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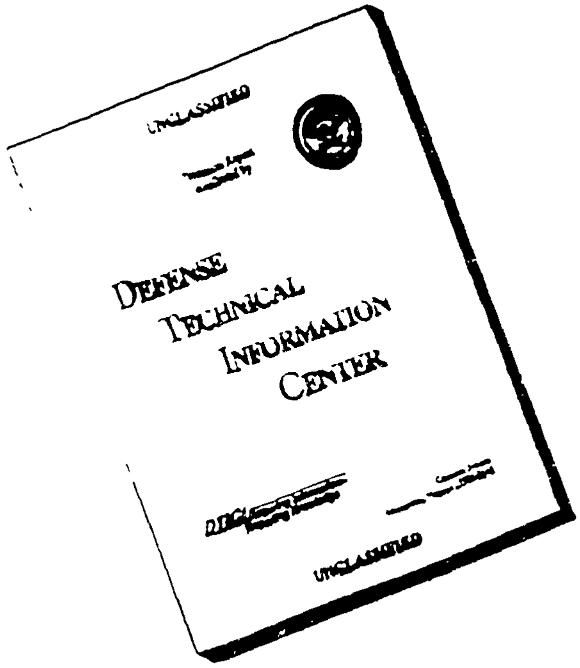

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REPORT 388

ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT

64 RUE DE VARENNE, PARIS VII

REPORT 388

A STUDY OF SOUNDING ROCKET SYSTEMS

by

K. M. RUS

JULY 1961

NORTH ATLANTIC TREATY ORGANISATION

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ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT

A STUDY OF SOUNDING ROCKET SYSTEMS

by

K.M. Russ

This Report is one in the Series 375-397, inclusive, presenting papers, with discussions, given at the AGARD Specialists' Meeting on 'The Use of Rocket Vehicles in Flight Research' at the Kurhaus Hotel, Scheveningen, Holland, 18-21 July 1961, sponsored by the AGARD Fluid Dynamics Panel

SUMMARY

This paper presents, for each of 18 existing sounding rocket systems, a short description, a sketch with overall dimensions, weight and maximum acceleration data, and two performance charts - apogee altitude versus payload for various launch angles, and altitude versus time for various payloads at a launch angle of 88 degrees. The aim is to aid in the preliminary selection of a vehicle for a specific payload mission.

CONTENTS

A STUDY OF SOUNDING ROCKET SYSTEMS†

K.M. Russ*

1. INTRODUCTION

The primary purpose of this paper is to aid in the preliminary selection of a vehicle for a specific payload mission. The flight performance data presented show a very broad flight regime for each vehicle. Modifications to the data have not been made to account for factors such as the launch site, launcher elevation limits, range safety and vehicle payload environment. Consideration of these factors usually results in limitations being placed on the flight regime. Some limitations may be removed by minor modifications while, in the case of range safety, the limitation may be revised with no modification as the vehicle builds a good operational history.

†*Acknowledgement:* The data accumulated for this study was accomplished under the National Aeronautics and Space Administration Contract No. NASI-1013. The cooperation of the numerous organizations mentioned in the text is greatly appreciated. Special recognition is given to the individuals in the Chance Vought Astronautics Division whose work on the contract made this paper possible.

**Astronautics Division, Chance Vought Corporation, Dallas, Texas, U.S.A.*

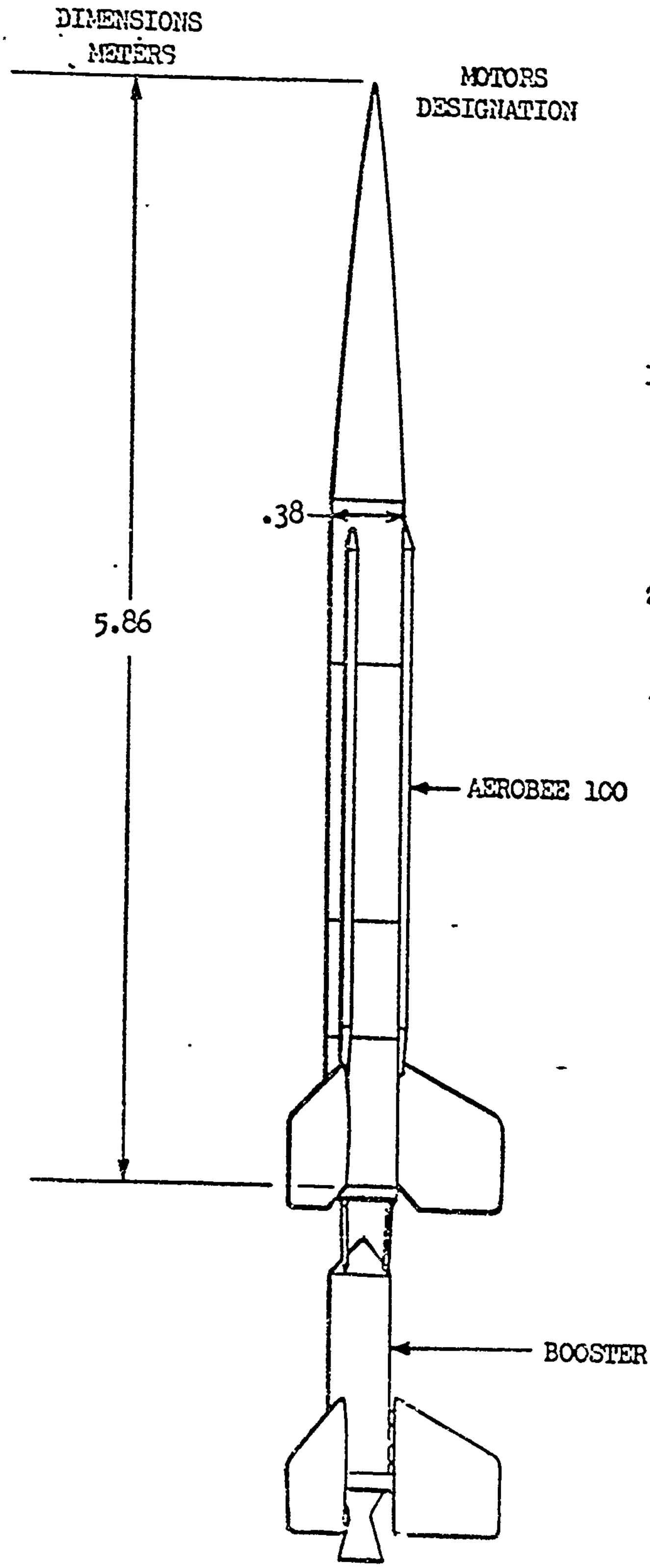
2. AEROBEE 100

The Aerobee 100, also known as the Aerobee Junior, is manufactured by the Aerojet-General Corporation. Figure 1 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 2 shows the vehicle performance for various launch angles. Figure 3 shows a plot of altitude versus time for three payloads.

The Aerobee 100 is a free-flight spun vehicle. The roll rate is variable since the sustainer fin incidence can be adjusted. The liquid propellants used are inhibited red fuming nitric acid and JP-4. Auxiliary thrust for launching is provided from a solid propellant booster rocket. Three fixed fins spaced 120 degrees apart furnish aerodynamic stability during flight. Provisions for command shutdown during flight can be provided, but the weights associated with this system were not incorporated into the performance calculations.

The Aerobee 100 is designed to be launched from existing Aerobee launching-tower facilities at Fort Churchill, Canada; White Sands Missile Range, New Mexico; Air Force Missile Development Center, Alamogordo, New Mexico; Eglin Air Force Base, Florida; and the portable tower used on the U.S.S. Norton Sound. The closed construction tower at Fort Churchill has a fixed rail 31.4 meters long, can be rotated 360 degrees and allows a 10 degree tilt in azimuth. Four successful firings have taken place at Fort Churchill. Two of the experiments were for ionosphere studies and two for Arctic meteorological photographs. A budgetary recurring cost for a vehicle is 13,960 dollars in lots of 10, not including payload.

AEROBEE 100



1. Performance Weights Less Payload and Booster

	Kilograms
Launch	356.0
B.O. 1st Stage	119.3

2. Payload Range
   22. to 114. Kilograms
3. Maximum Acceleration
   15 g's

Fig. 1

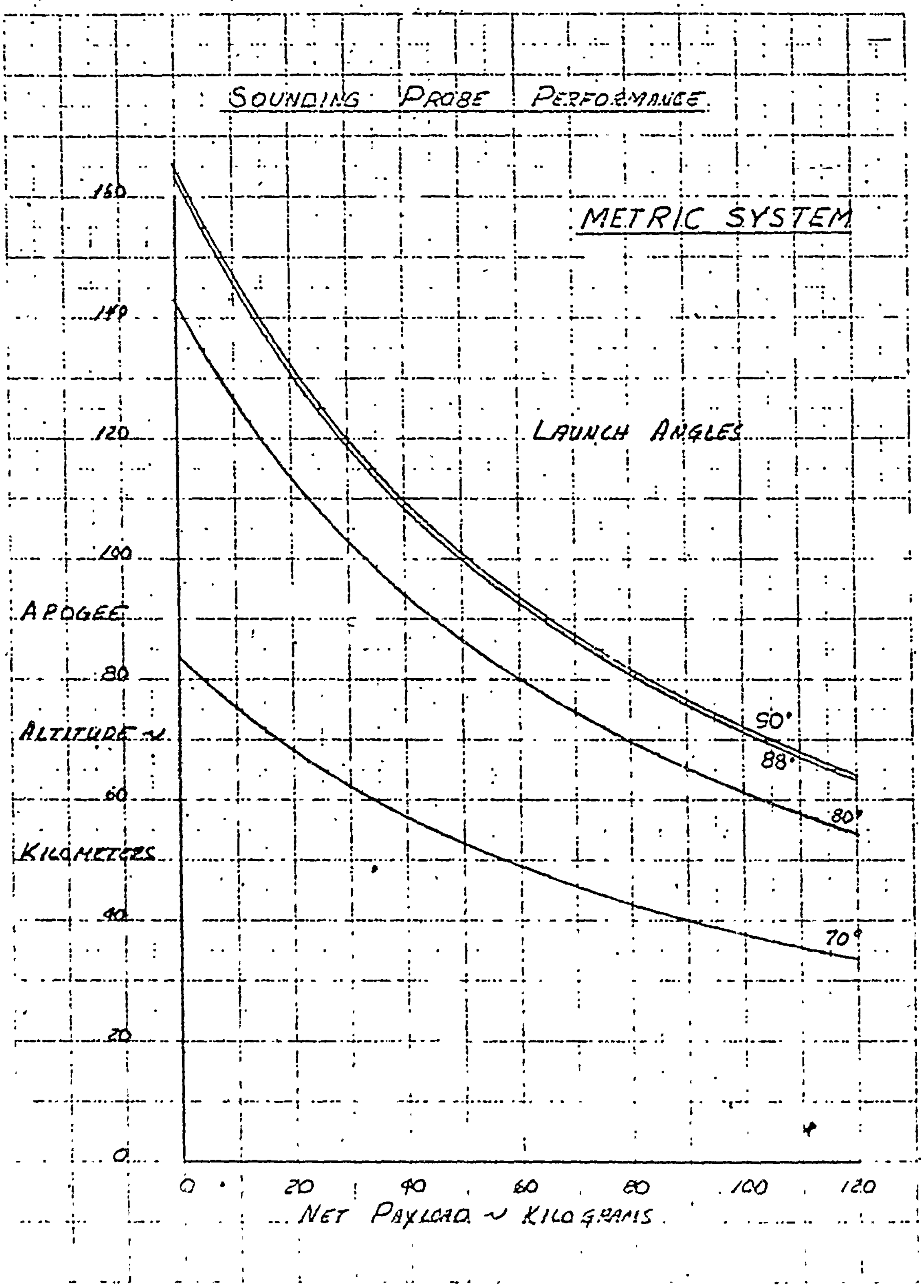

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
LAUNCH ANGLES
90°
88°
80°
70°
APOGEE ALTITUDE ~ KILOMETERS
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
NET PAYLOAD ~ KILOGRAMS

Fig. 2

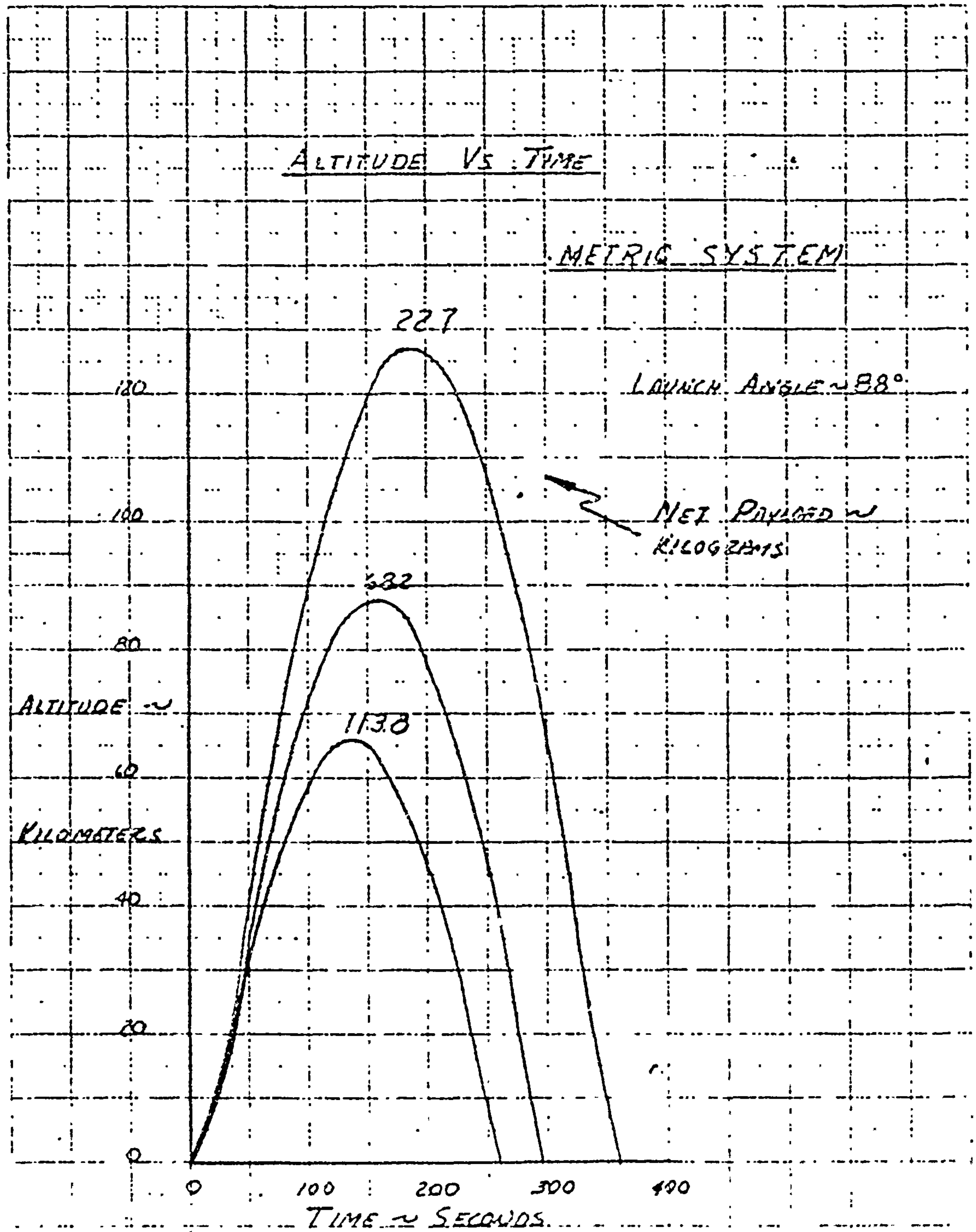

ALTITUDE VS. TIME
METRIC SYSTEM
LAUNCH ANGLE ~ 88°
NET PAYLOAD ~
KILOGRAMS
22.7
68.2
113.8
ALTITUDE ~
KILOMETERS
120
100
80
60
40
20
0
0
100
200
300
400
TIME ~ SECONDS

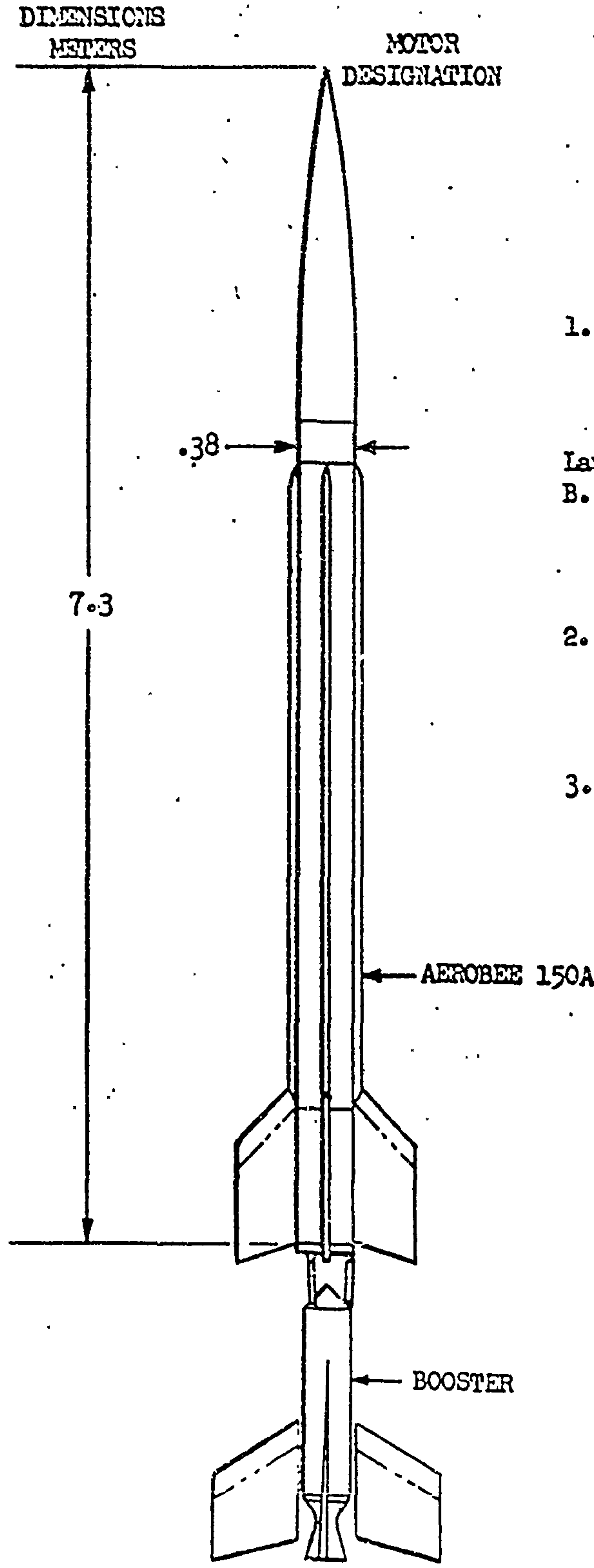
Fig. 3

3. AEROBEE 150A

The development of the Aerobee 150A was sponsored by the Goddard Space Flight Center of the National Aeronautics and Space Administration under a contract to Aerojet-General Corporation. The vehicle is a four-fin version of the three-fin 150, also known as the Aerobee-Hi. Figure 4 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 5 shows the vehicle performance for various launch angles. Figure 6 shows a plot of altitude versus time for three payloads.

The Aerobee 150A consists basically of integral liquid propellant tanks which also act as the main rocket body, the aft structure which supports the fins and contains the thrust chamber, and a forward skirt that contains the pressurization system. The fuel is a mixture of 65% aniline and 35% furfuryl alcohol. The oxidizer is inhibited red fuming nitric acid (7% NO_2). The pressurizing gas is helium. Three tunnels or shrouds are provided between the forward skirt and the aft structure for the gas pressurization lines and instrumentation wiring. Mounted equidistant between the shrouds, fore and aft, are two sets of riding lugs which support the vehicle between the rails in the launching tower. The four sustainer fins are spaced 90 degrees apart and may be canted from zero to twenty minutes. Auxiliary thrust for launching is provided from a solid propellant booster. The booster fins are presently installed at 2½ degrees cant to impart a roll rate as the vehicle leaves the four-rail launching tower. The launching tower is at Wallops Island, Virginia; the rail is 48.8 meters long. There have been eleven firings, of which ten were successful. A budgetary recurring cost for a vehicle is 28,950 dollars in lots of 10, not including the payload.

AEROBEE 150A



1. Performance Weights Less Payload and Booster

	Kilograms
Launch	611.2
B. O. 1st Stage	132.9

2. Payload Range

   45. to 136. Kilograms

3. Maximum Acceleration

   11 g's

Fig. 4

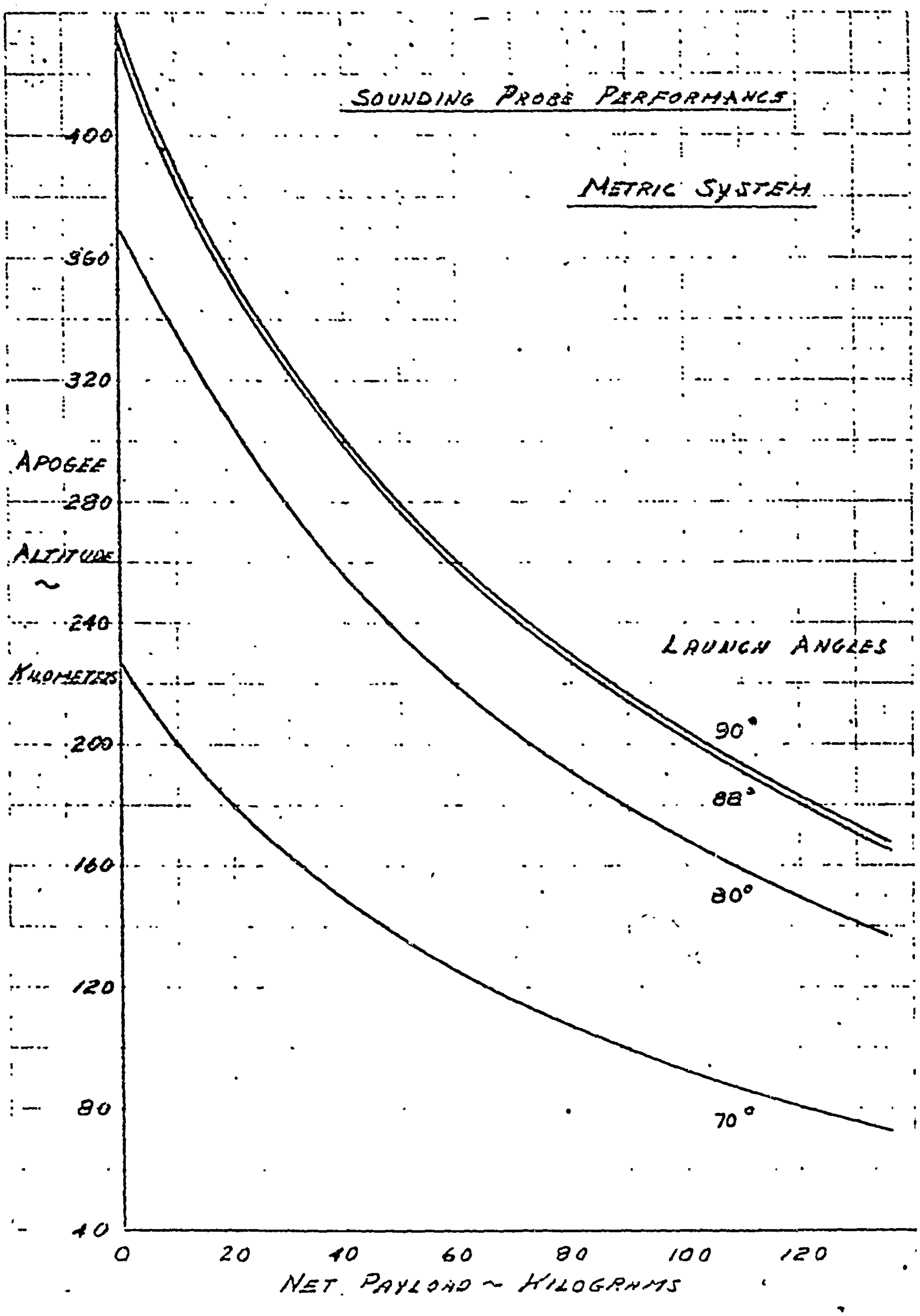

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
APOGEE
ALTITUDE
~
KILOMETERS
400
360
320
280
240
200
160
120
80
40
LAUNCH ANGLES
90°
88°
80°
70°
0
20
40
60
80
100
120
NET PAYLOAD ~ KILOGRAMS

Fig. 5

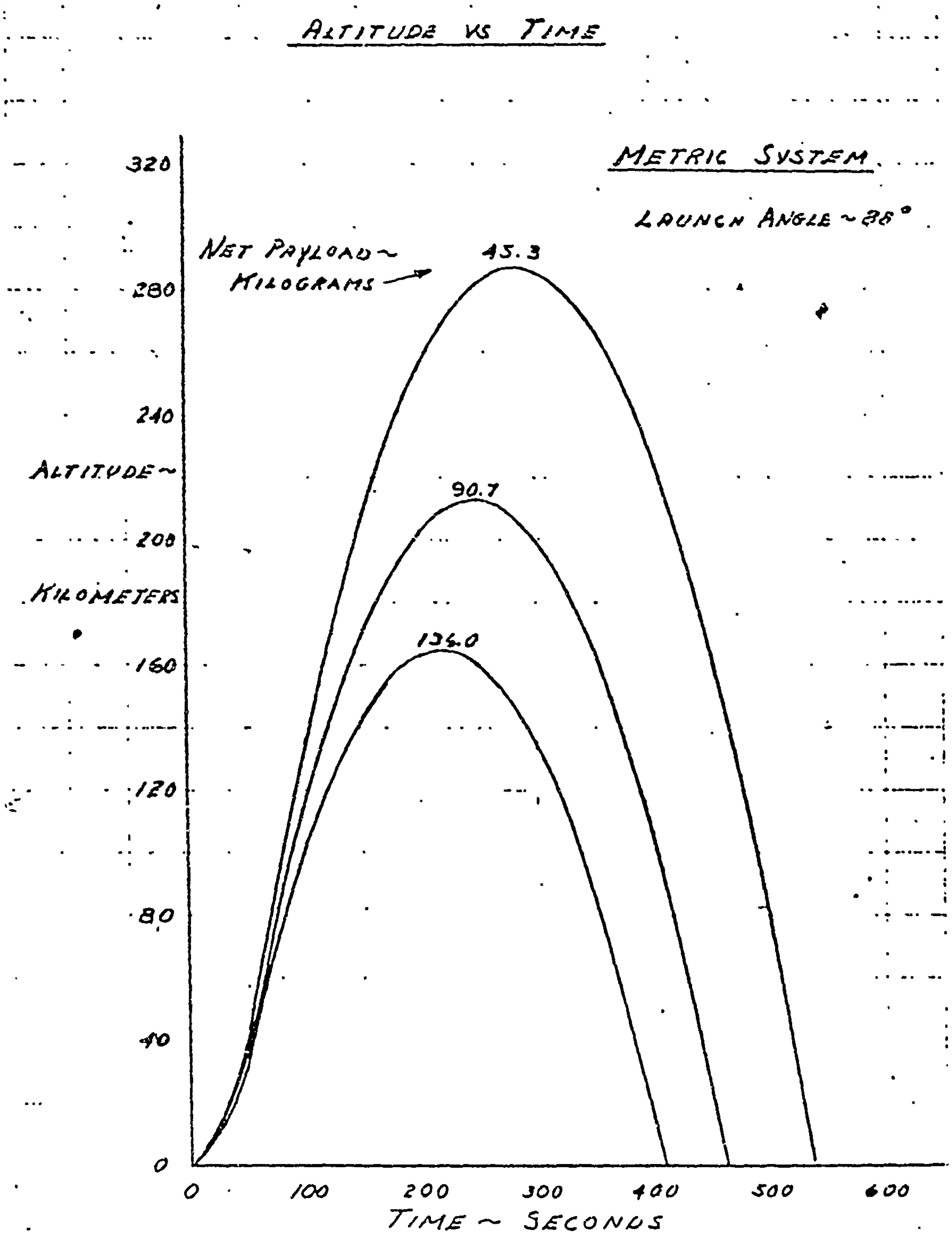

ALTITUDE VS TIME
METRIC SYSTEM
LAUNCH ANGLE ~ 88°
NET PAYLOAD ~
KILOGRAMS
45.3
90.7
136.0
320
280
240
ALTITUDE ~
200
KILOMETERS
160
120
80
40
0
0
100
200
300
400
500
600
TIME ~ SECONDS

Fig. 6

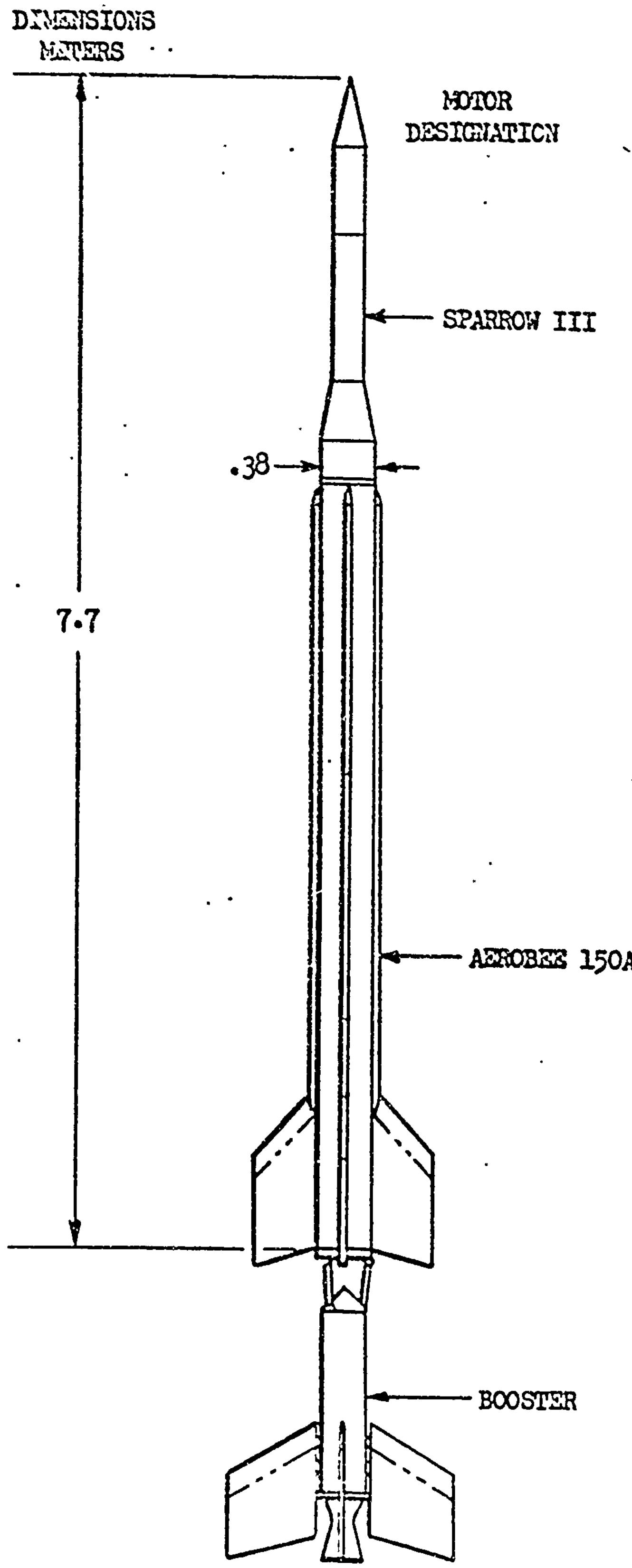
4. AEROBEE 300A

The Aerobee 300A is manufactured by the Aerojet-General Corporation. The configuration is the same as the 150A with an added upper step solid propellant motor. The three-fin 150 and four-fin 150A with the added motor are designated the 300 and 300A, respectively. The 300 series are also known as Spaerobees. The performance capability of the vehicles is similar. Figure 7 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 8 shows the vehicle performance for various launch angles. Figure 9 shows a plot of altitude versus time for three payloads.

The liquid fuel tanks can be held in a pressurized condition for extended periods of time. The ignition of the second stage engine is signalled by a decrease in first step chamber pressure.

The Aerobee 300A has been launched from Wallops Island, Virginia and the 300 from Fort Churchill, Canada. The only Aerobee 300A firing as of 1960 was on August 3, 1960. The objective was to measure the ionosphere ion density and electron temperature. The flight was successful. The Aerobee 300 has been flown 19 times, of which five were used in the United States International Geophysical Year Atmosphere Rocket Operations. A budgetary recurring cost for a vehicle is 33,340 dollars in lots of 10, not including the payload.

AEROBEE 300A



1. Performance Weights Less Payload and Booster

	Kilograms
Launch	683.3
B.O. 1st	205.1
Fire 2nd	61.24
B.O. 2nd	29.89

2. Payload Range

   9. to 46. Kilograms

3. Maximum Acceleration

   57 g's

Fig. 7

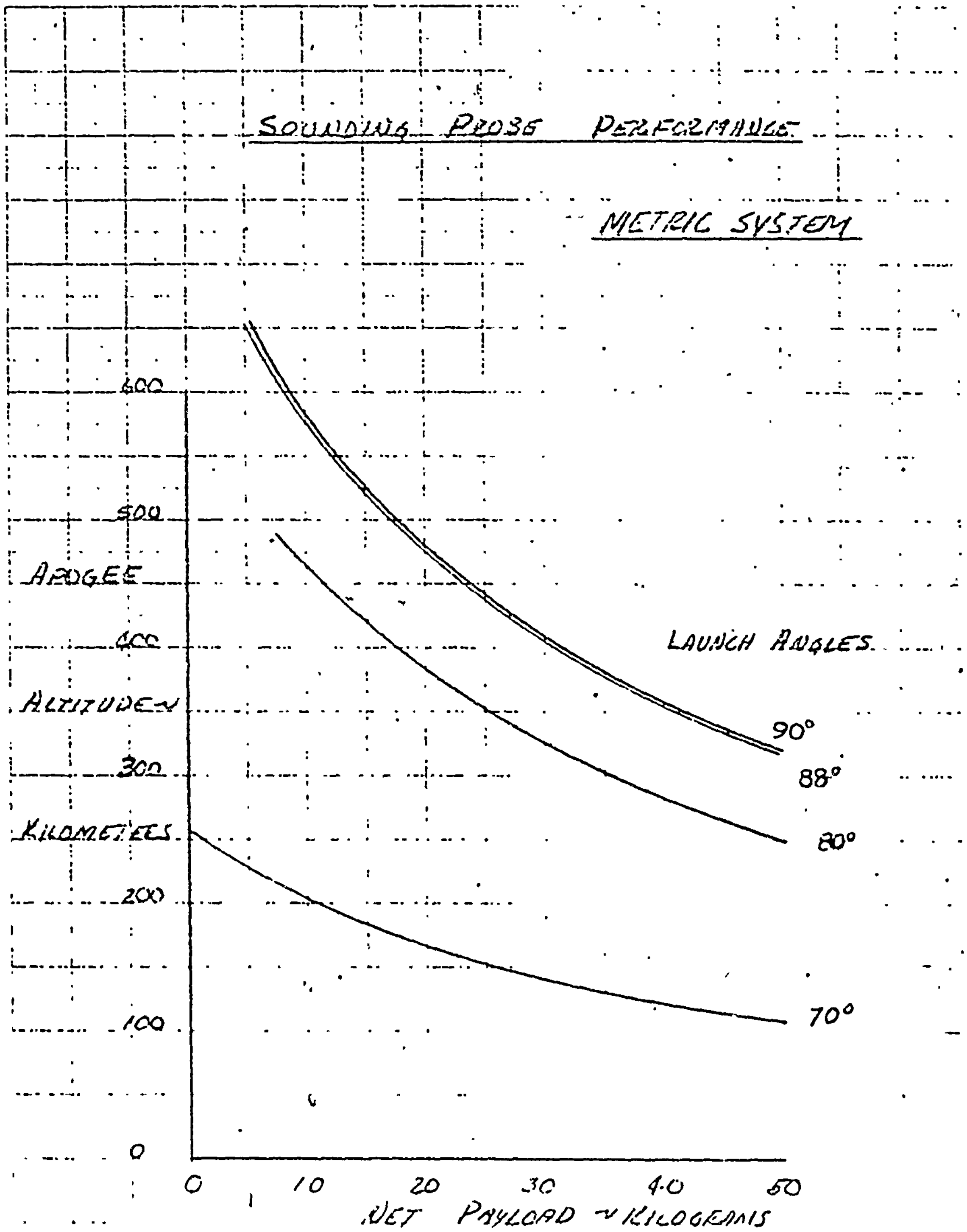

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
APOGEE ALTITUDE ~ KILOMETERS
600
500
400
300
200
100
0
LAUNCH ANGLES
90°
88°
80°
70°
0
10
20
30
40
50
NET PAYLOAD ~ KILOGRAMS

Fig. 8

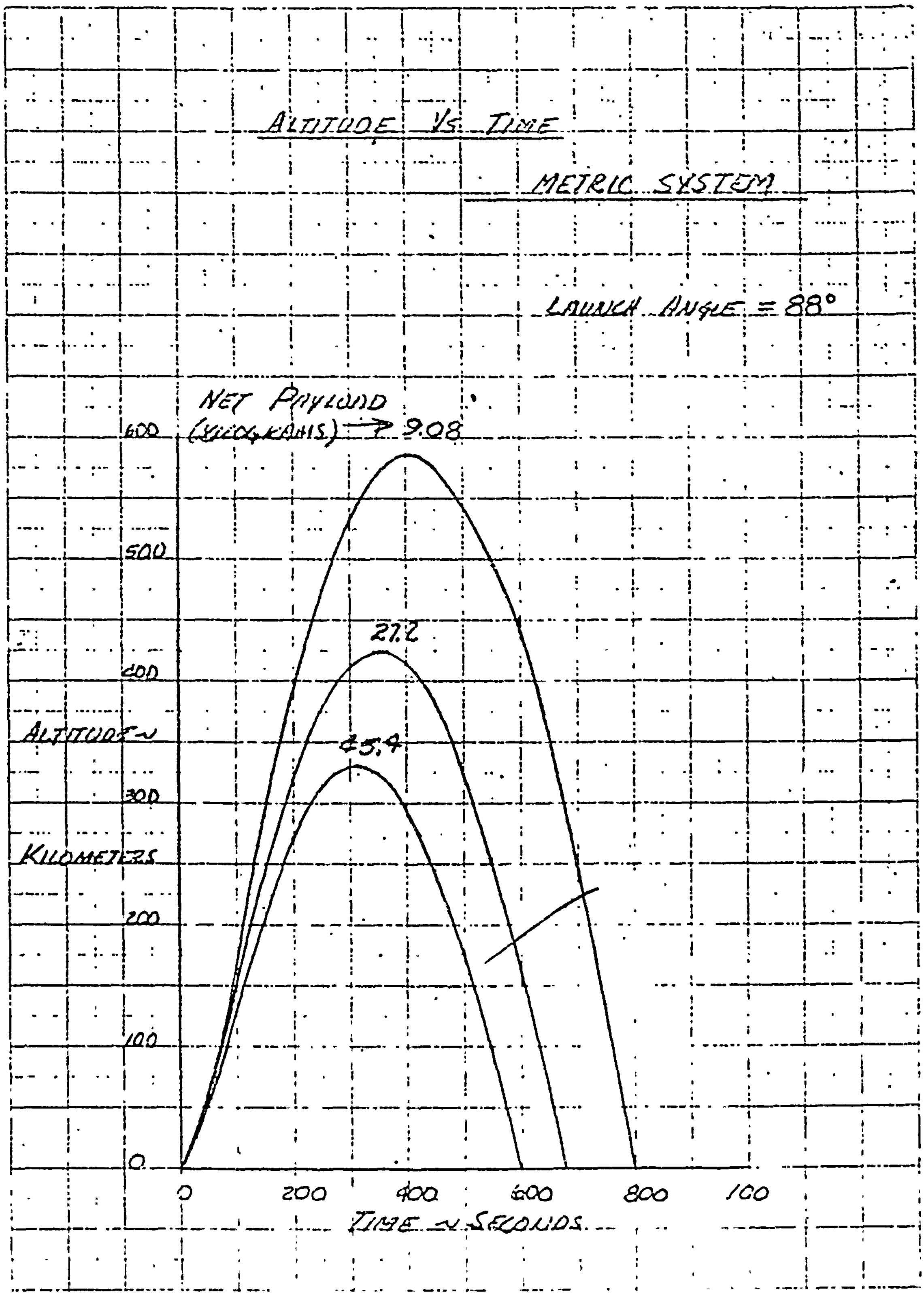

ALTITUDE VS TIME
METRIC SYSTEM
LAUNCH ANGLE = 88°
NET PAYLOAD (KILOGRAMS) → 9.08
27.2
45.4
600
500
400
300
200
100
0
ALTITUDE ~ KILOMETERS
0
200
400
600
800
100
TIME ~ SECONDS

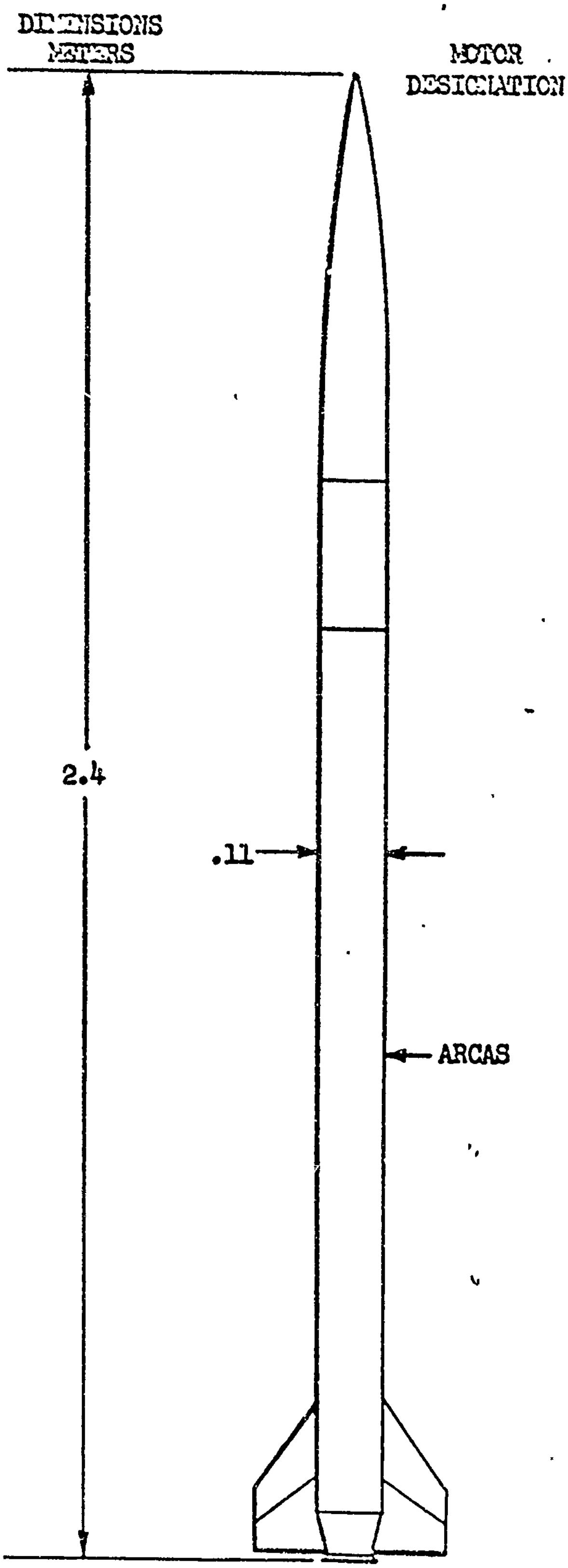
Fig. 9

5. ARCAS

The Arcas was developed by Atlantic Research Corporation for conducting atmosphere soundings under sponsorship of the three services, as represented by the Office of Naval Research, Air Force Cambridge Research Center, and the United States Army Signal Research and Development Laboratories. Figure 10 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 11 shows the vehicle performance for various launch angles. Figure 12 shows a plot of altitude versus time for three payloads.

The Arcas has four fins spaced 90 degrees apart. The vehicle employs an end-burning solid propellant rocket. The structure above the motor consists of a nose cone, parachute container, and separation device. The nominal payload employs a parachute designed to lower an instrumentation package from 61,000 meters to 24,000 meters at a descent rate permitting meterological measurements. The launcher is a closed breech type using the entrapped exhaust gases of the rocket to accelerate the missile by piston action. As of January, 1961, the Arcas has been successfully fired 400 times, which represents approximately 90% of the total firings. A budgetary recurring cost for a vehicle is 1,453 dollars in lots of 10, not including the payload.

ARCAS



1. Performance Weights Less Payload

	Kilograms
Launch	30.84
B.O. 1st	12.25

2. Payload Range

   .7 to 8. Kilograms

3. Maximum Acceleration

   46 g's

Fig. 10

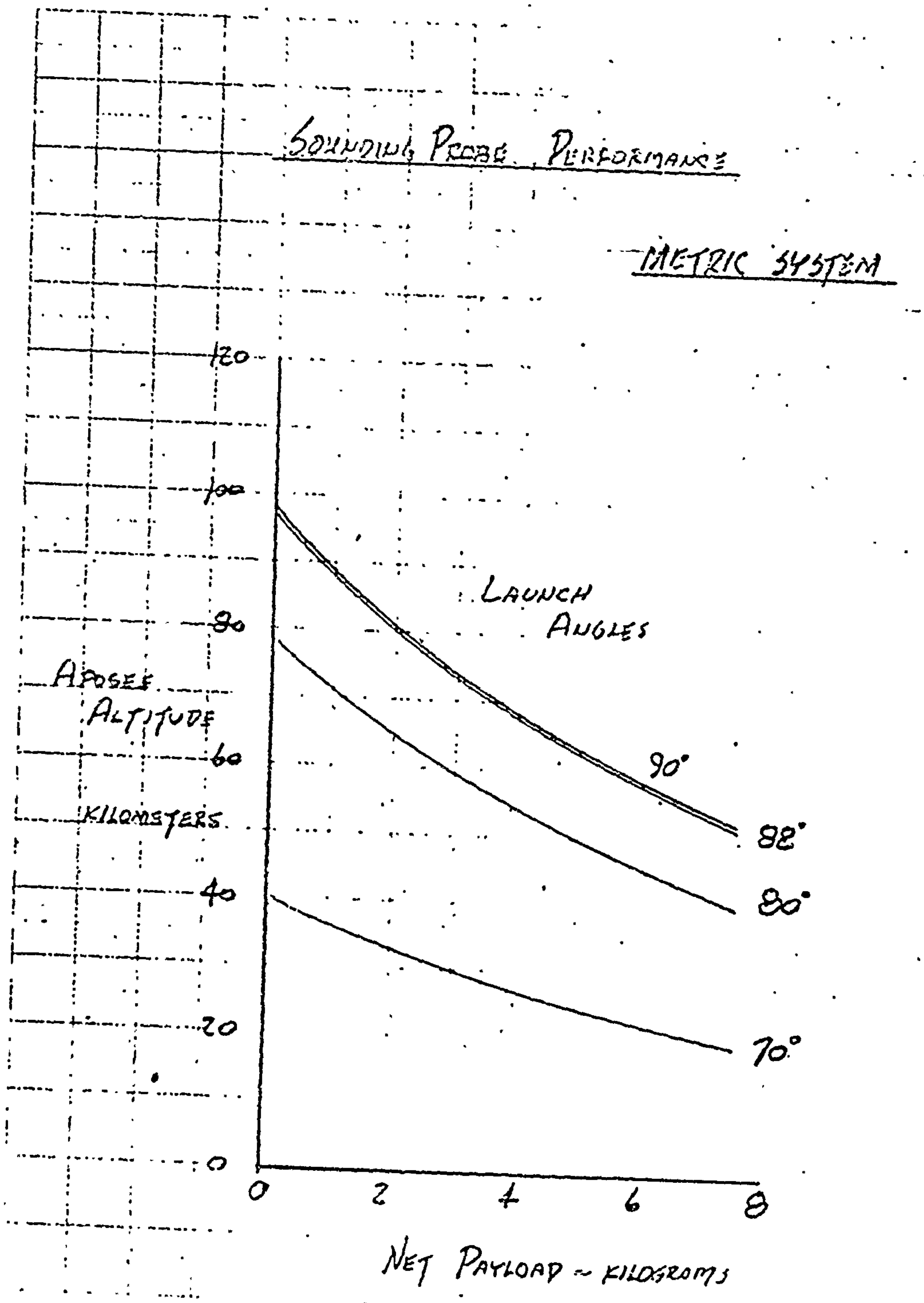
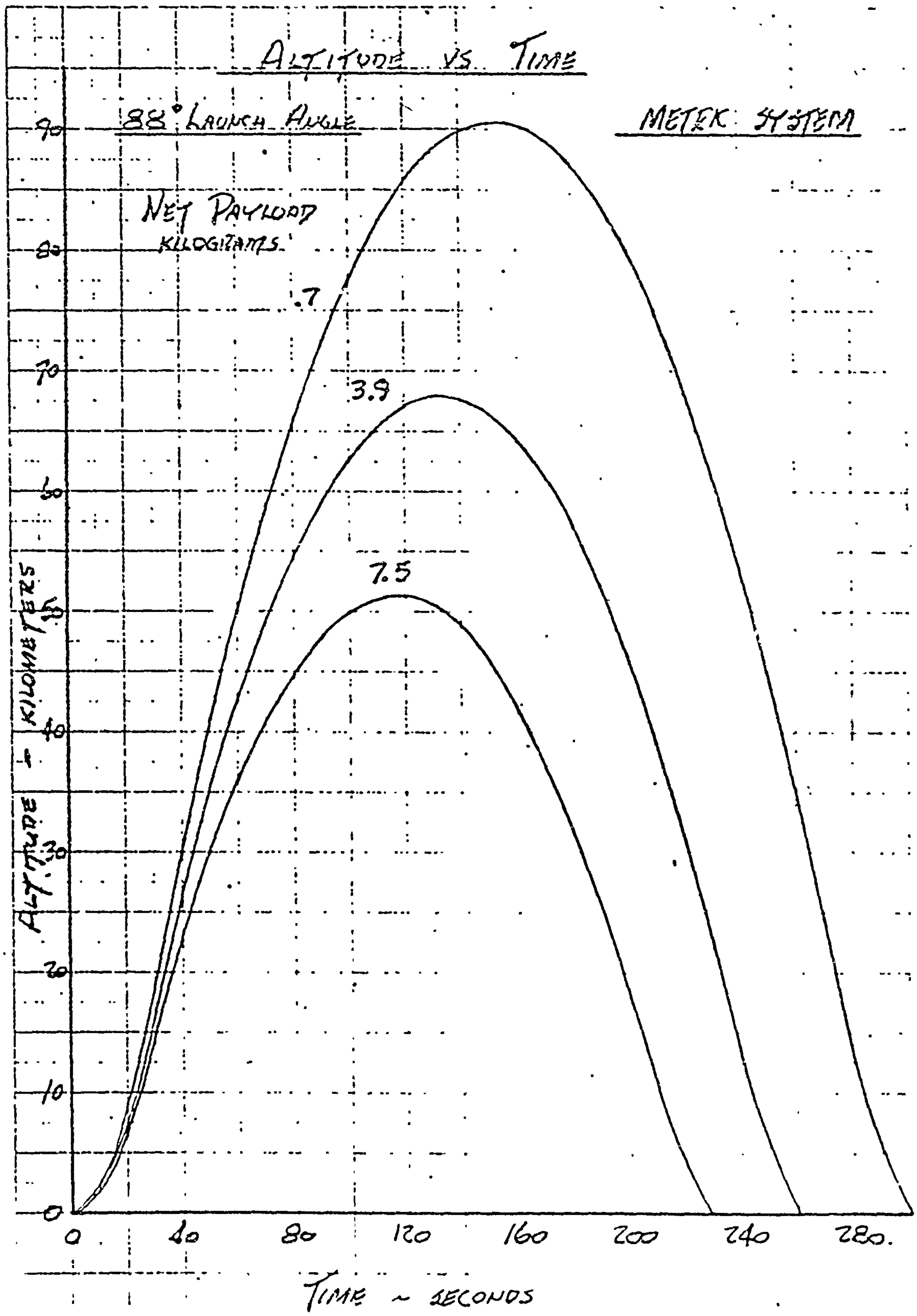

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
120
100
80
60
40
20
0
APOGEE ALTITUDE KILOMETERS
LAUNCH ANGLES
90°
88°
80°
70°
0
2
4
6
8
NET PAYLOAD ~ KILOGRAMS

Fig. 11



ALTITUDE VS. TIME
88° LAUNCH ANGLE
METEK SYSTEM
NET PAYLOAD KILOGRAMS
.7
3.9
7.5
0
10
20
30
40
50
60
70
80
90
0
40
80
120
160
200
240
280.
ALTITUDE ~ KILOMETERS
TIME ~ SECONDS

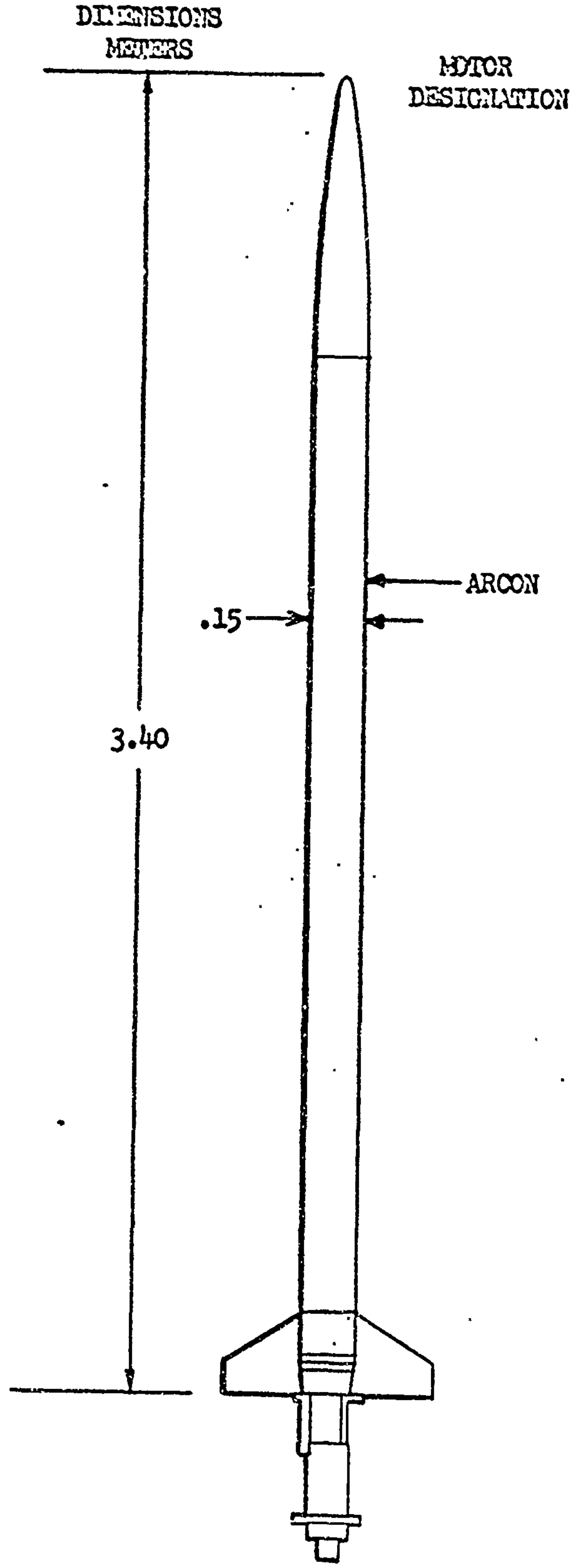
Fig. 12

6. ARCON

Development work on the Arcon vehicle was initiated in 1955 by the Atlantic Research Corporation for the Naval Research Laboratory's Rocketsonde Branch under a Bureau of Ordance contract. Figure 13 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 14 shows the vehicle performance for various launch angles. Figure 15 shows a plot of altitude versus time for three payloads.

The Acron uses a solid propellant rocket motor with four fins spaced 90 degrees apart welded on the aft section. A small solid propellant rocket is employed to boost the Acron from its launcher. A four-rail mobile launcher 10.7 meters long, trainable over 360 degrees azimuth and 90 degrees elevation by remote control, is used for launching. Three performance flight tests were conducted by the Naval Research Laboratory in July of 1958. Six additional performance flights were conducted by the National Aeronautics and Space Administration, Goddard Space Flight Center, in the summer of 1959. The first three NRL flights were unsuccessful and three of the last six NASA flights were successful. In the NASA series, pitch-roll coupling was apparently responsible for the breakup of two vehicles, while the other experienced a nozzle burn-through at launch. Accurate control of the roll rate is necessary before high reliability of the Arcon can be achieved. Further development of the vehicle is presently suspended. A budgetary recurring cost for a vehicle is 4,875 dollars in lots of 10, not including the payload.

ARCON

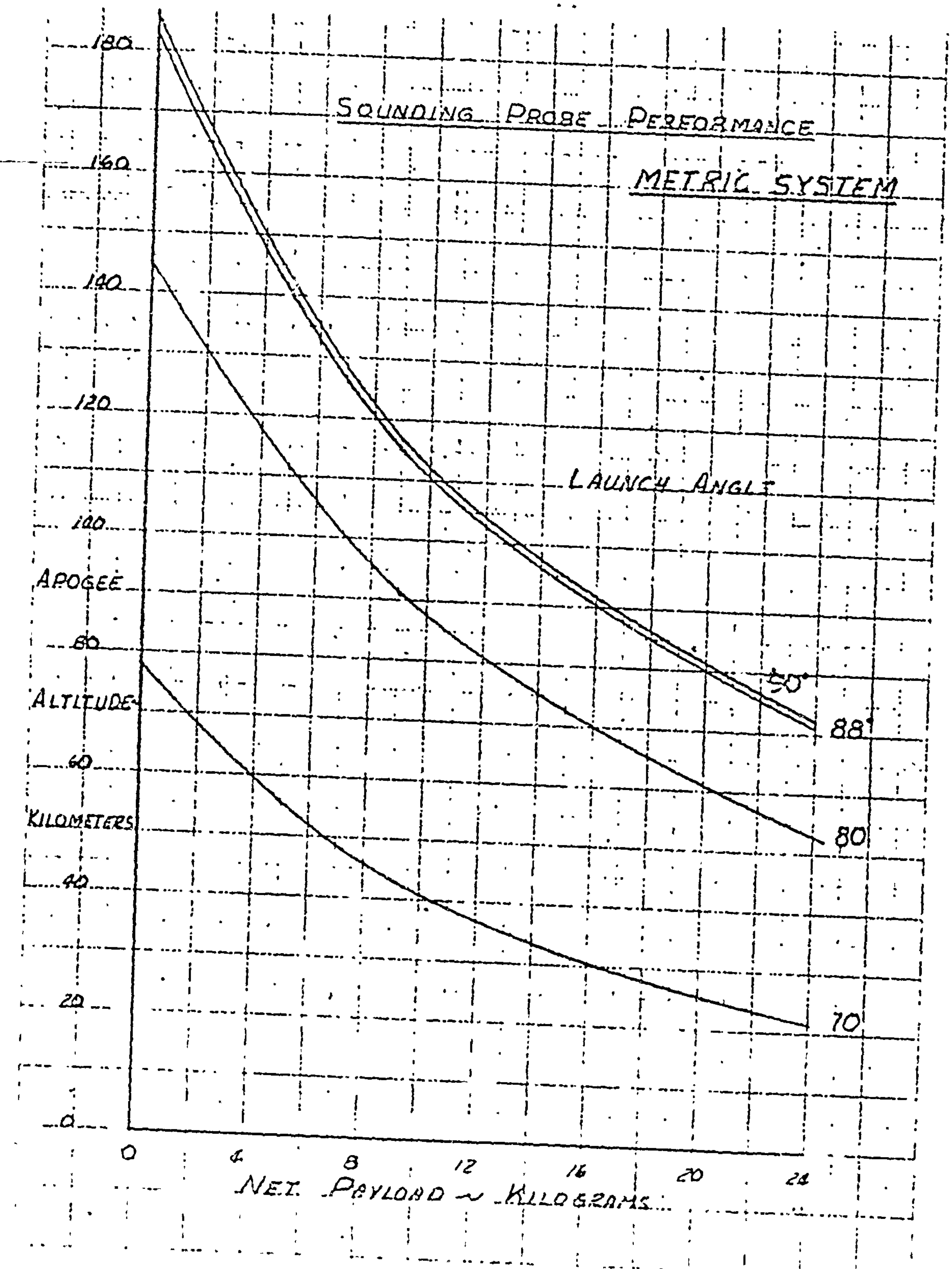


1. Performance Weights
   Less Payload and Booster

	Kilograms
Launch	96.6
B.O. 1st Stage	30.6

2. Payload Range
   9. to 23. Kilograms
3. Maximum Acceleration
   14.6 g's

Fig. 13



SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
LAUNCH ANGLE
50°
88°
80
70
APOGEE
ALTITUDE
KILOMETERS
180
160
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
NET PAYLOAD ~ KILOGRAMS

Fig. 11

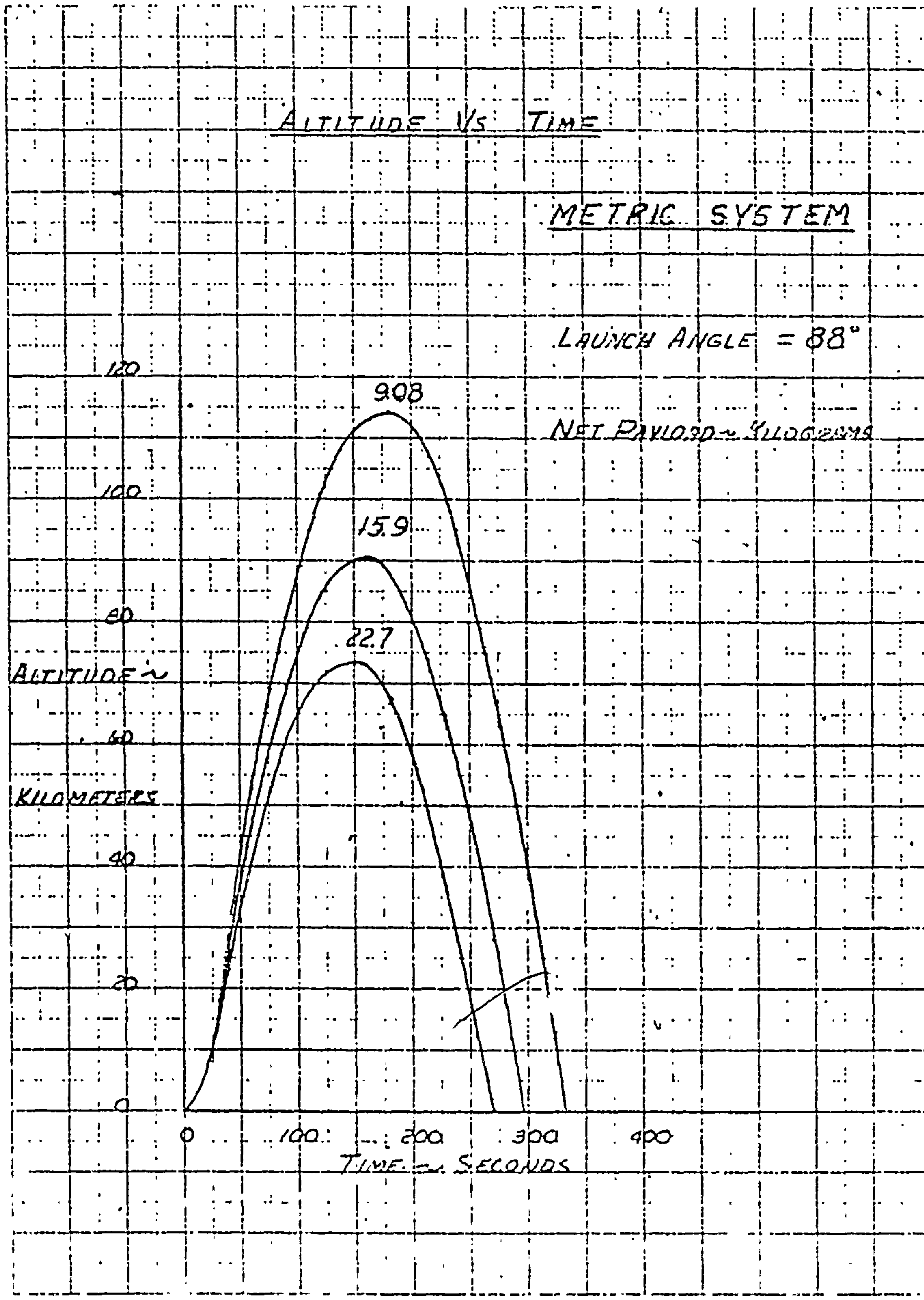

ALTITUDE VS TIME
METRIC SYSTEM
LAUNCH ANGLE = 88°
NET PAYLOAD ~ KILOGRAMS
9.08
15.9
22.7
120
100
80
60
40
20
0
ALTITUDE ~
KILOMETERS
0
100
200
300
400
TIME ~ SECONDS

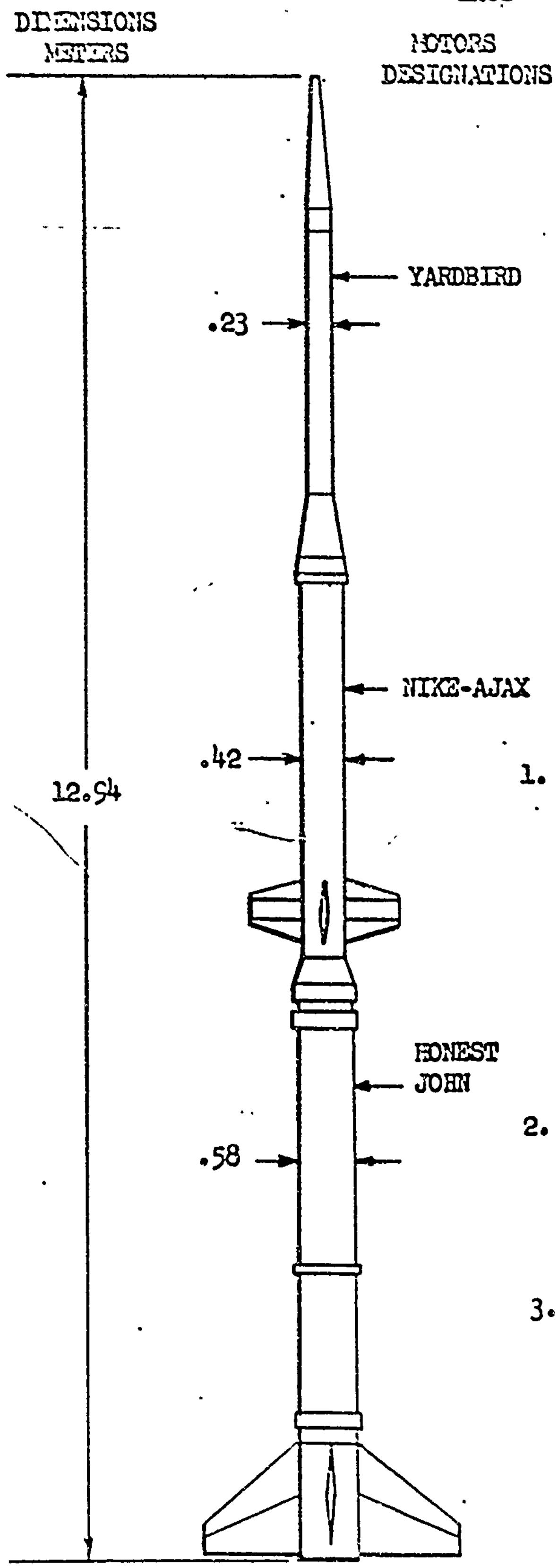
Fig. 15

7. EXOS

The Exos was manufactured by the University of Michigan with the cooperation of the National Aeronautics and Space Administration under sponsorship of the Air Force Cambridge Research Center. Figure 16 shows a sketch of the vehicle staging weights, payload weight range, and maximum acceleration. Figure 17 shows the vehicle performance for various launch angles. Figure 18 shows a plot of altitude versus time for three payloads.

The Exos uses three solid propellant rocket motors. The vehicle is free-flight with fin and flare stabilization. The first step separates from the second stage at burnout and the remainder of the vehicle coasts for 25 seconds. The second stage is ignited by timer and batteries and at burnout the pressure drop signals third stage ignition. Separation is effected by a blow-out diaphragm. The Exos was launched from a converted Honest John launcher which has a 3.68 meter guidance rail. However, the Exos can be fired with minor modification from a simple beam launcher with no guide rail required. Such launchers exist at the NASA Wallops Island, Virginia; Eglin Air Force Base, Florida; Atlantic Missile Range; Pacific Missile Range; and White Sands Proving Ground, New Mexico. The Exos has been successfully fired twice from Wallops Island utilizing a short burning solid propellant Recruit motor as the third step. The vehicle as shown was fired once from Eglin Air Force Base. This unsuccessful flight was believed caused by launcher interference. A budgetary recurring cost for a vehicle is 19,937 dollars in lots of 10, not including the payload.

EXOS



1. Performance Weights Less Payload

	Kilograms
Launch	2662.
B.O. 1st	1674.
Fire 2nd	773.6
B.O. 2nd	427.1
Fire 3rd	183.1
B.O. 3rd	61.5

2. Payload Range

18. to 46 Kilograms

3. Maximum Acceleration

78 g's

Fig. 16

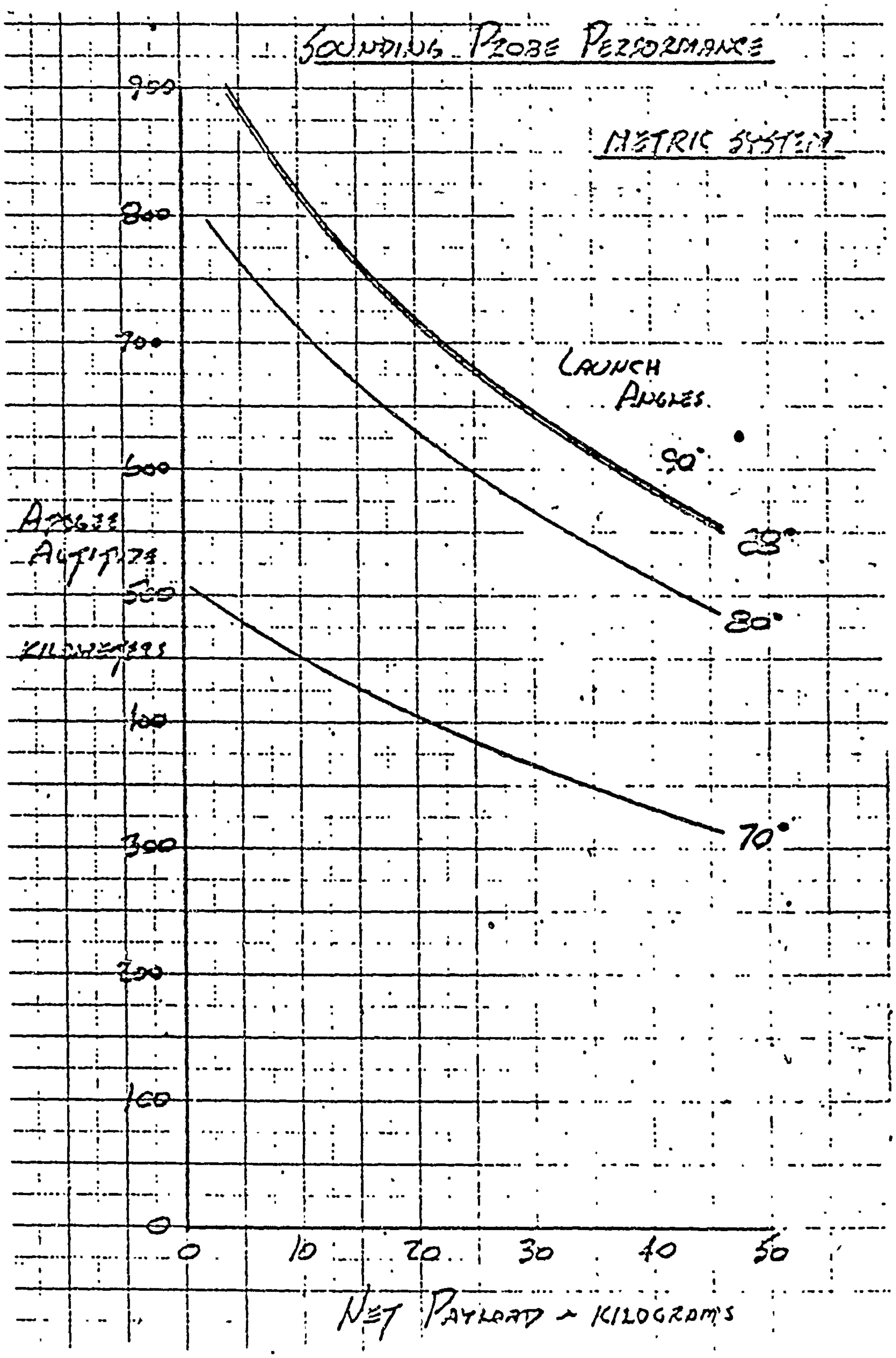
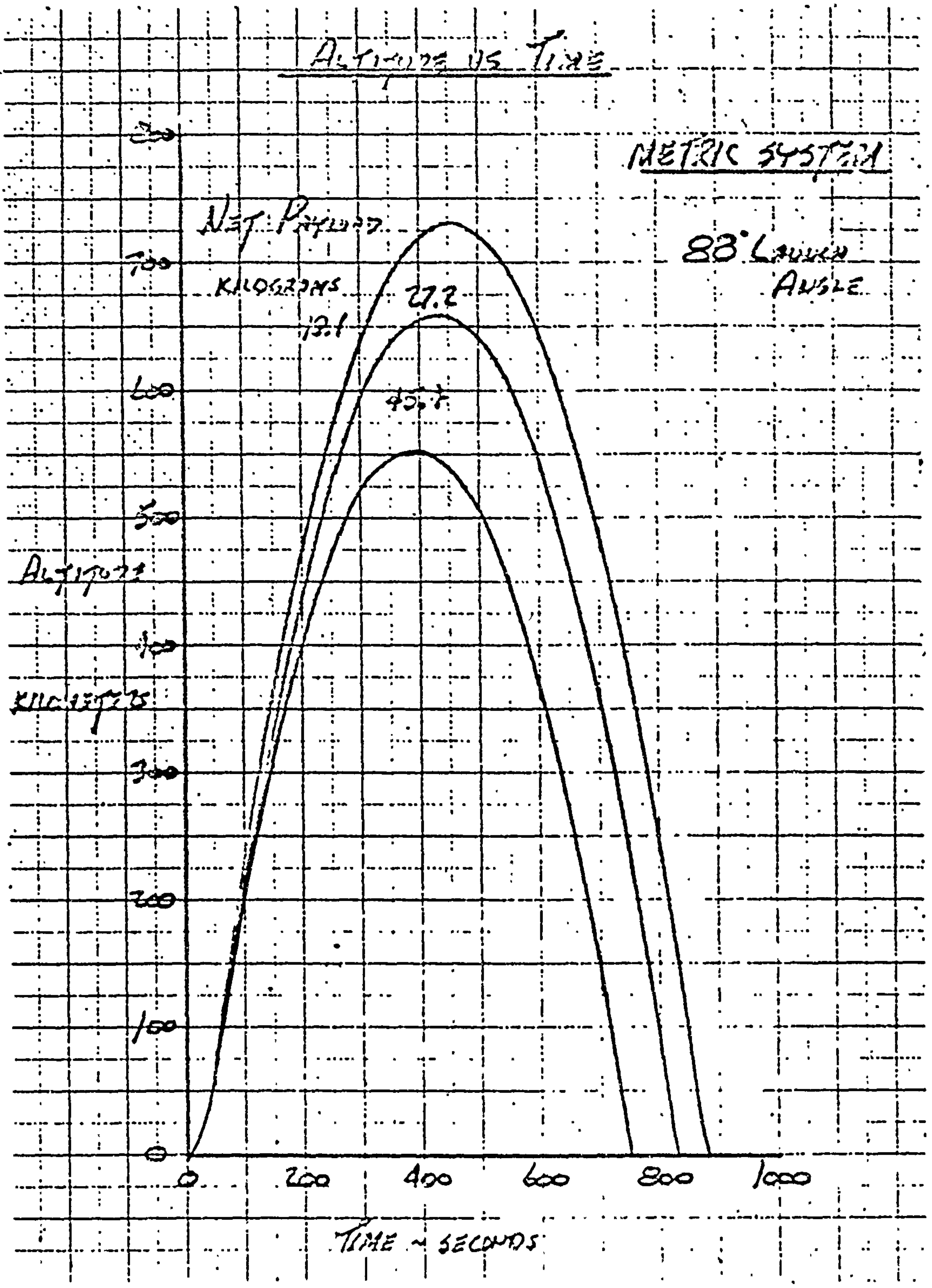

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
LAUNCH ANGLES
90°
88°
80°
70°
APOGEE ALTITUDE KILOMETERS
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
NET PAYLOAD ~ KILOGRAMS

Fig. 17



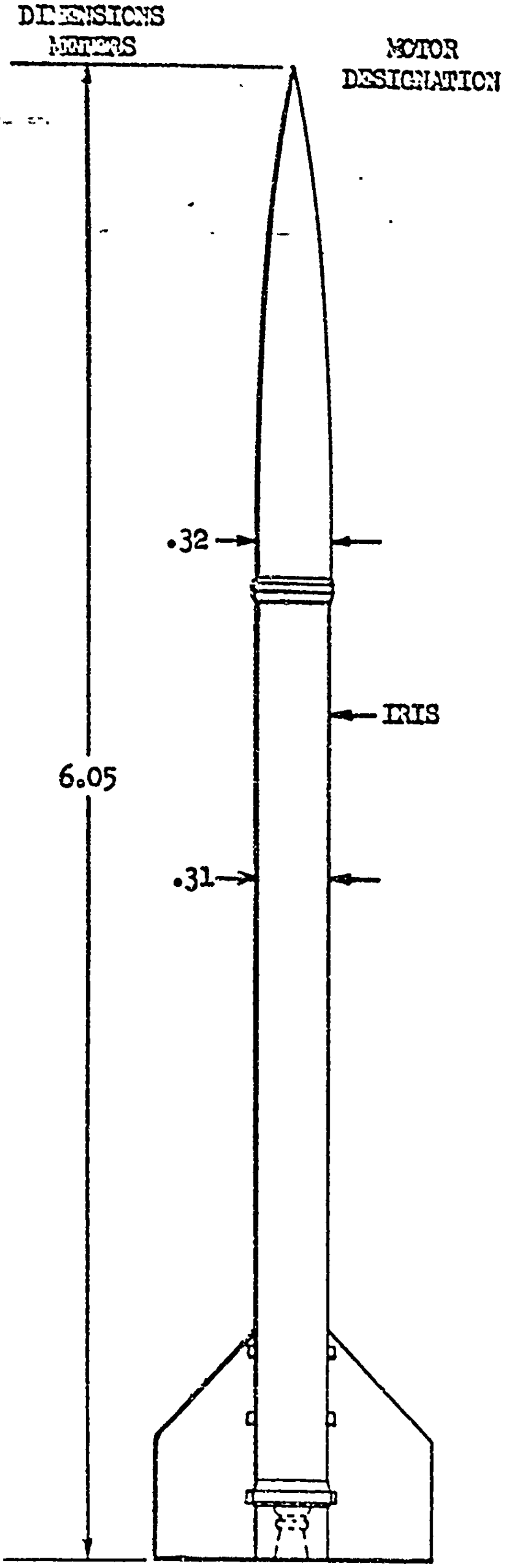
ALTITUDE VS TIME
METRIC SYSTEM
NET PAYLOAD
KILOGRAMS
27.2
13.1
45.4
88° LAUNCH ANGLE
ALTITUDE
KILOMETERS
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
TIME ~ SECONDS

Fig. 18

8. IRIS

Design studies and early work on the Iris motor development were initiated for the Naval Research Laboratory by the Atlantic Research Corporation in 1956. Motor and vehicle development were completed for the National Aeronautics and Space Administration, Goddard Space Flight Center, in 1960 and included a six-round motor qualification testing program. Figure 19 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 20 shows the vehicle performance for various launch angles. Figure 21 shows a plot of altitude versus time for three payloads.

The Iris motor uses solid propellant and is an end-burner. Auxiliary thrust is supplied by a unit consisting of seven solid rocket motors, 10.2 centimeters in diameter and burning for 0.8 seconds. The booster is not mechanically attached to the Iris and falls away after the rocket exits from the tower. The ignition system incorporates a relay with a built-in time delay to insure that the booster ignites before the sustainer. The Iris is designed to be launched from the 43.8 meter, 4-rail tower at Wallops Island, Virginia. Three performance flight tests were conducted by Goddard Space Flight Center in late 1960 and early 1961. The first two firings were successful and no information is yet available as to why the third flight was unsuccessful. Twelve additional Iris vehicles will be flown in the near future. A budgetary recurring cost for a vehicle is 13,470 dollars in lots of 10, not including the payload.



1. Performance Weights Less Payload

	Kilograms
Launch	550.7
B.O. 1st Stage	112.0

2. Payload Range

   34. to 91. Kilograms

3. Maximum Acceleration

   13.9 g's

Fig. 19

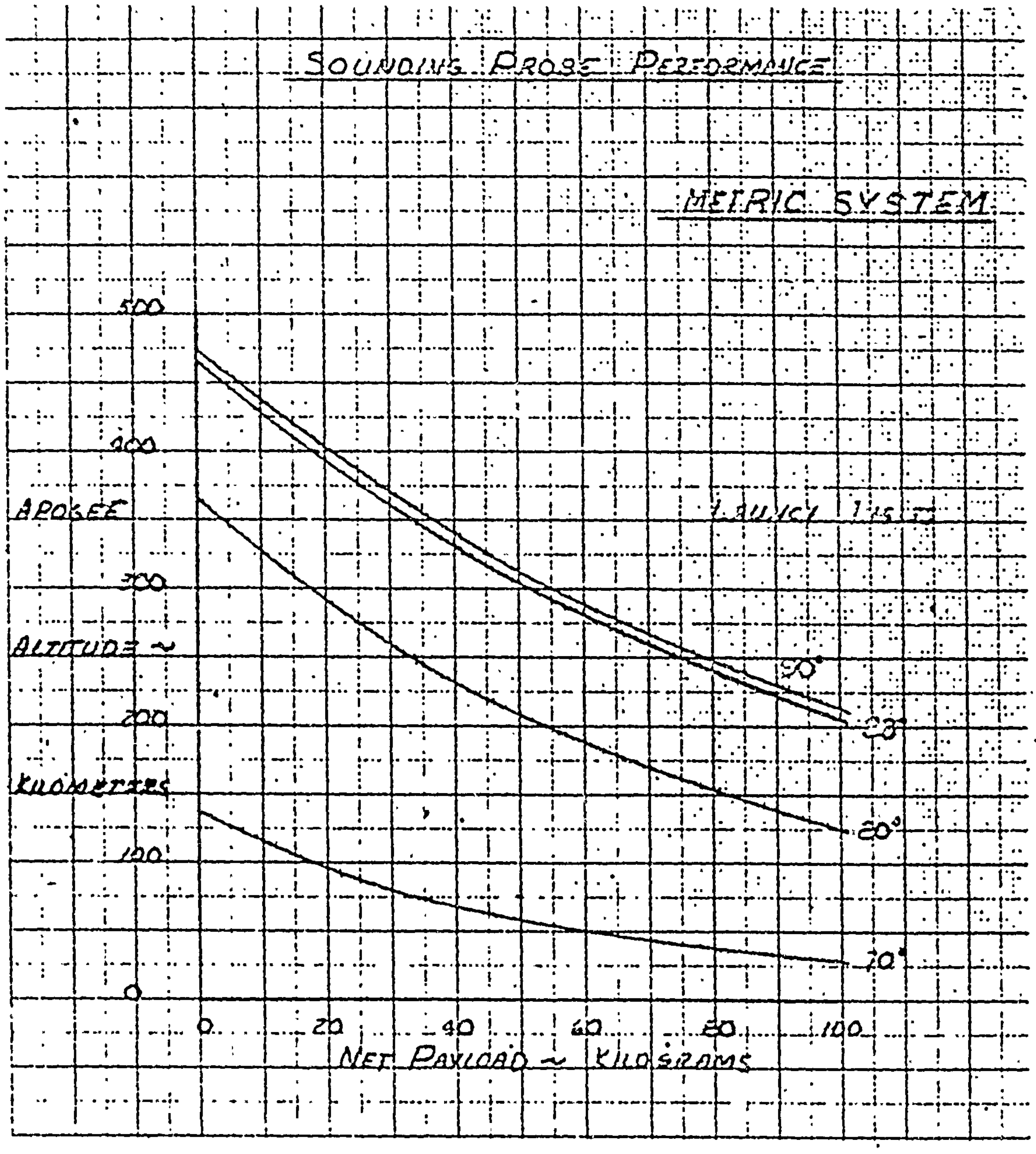

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
APOGEE
ALTITUDE ~
KILOMETERS
500
400
300
200
100
0
90°
0
20
40
60
80
100
NET PAYLOAD ~ KILOGRAMS

Fig. 20

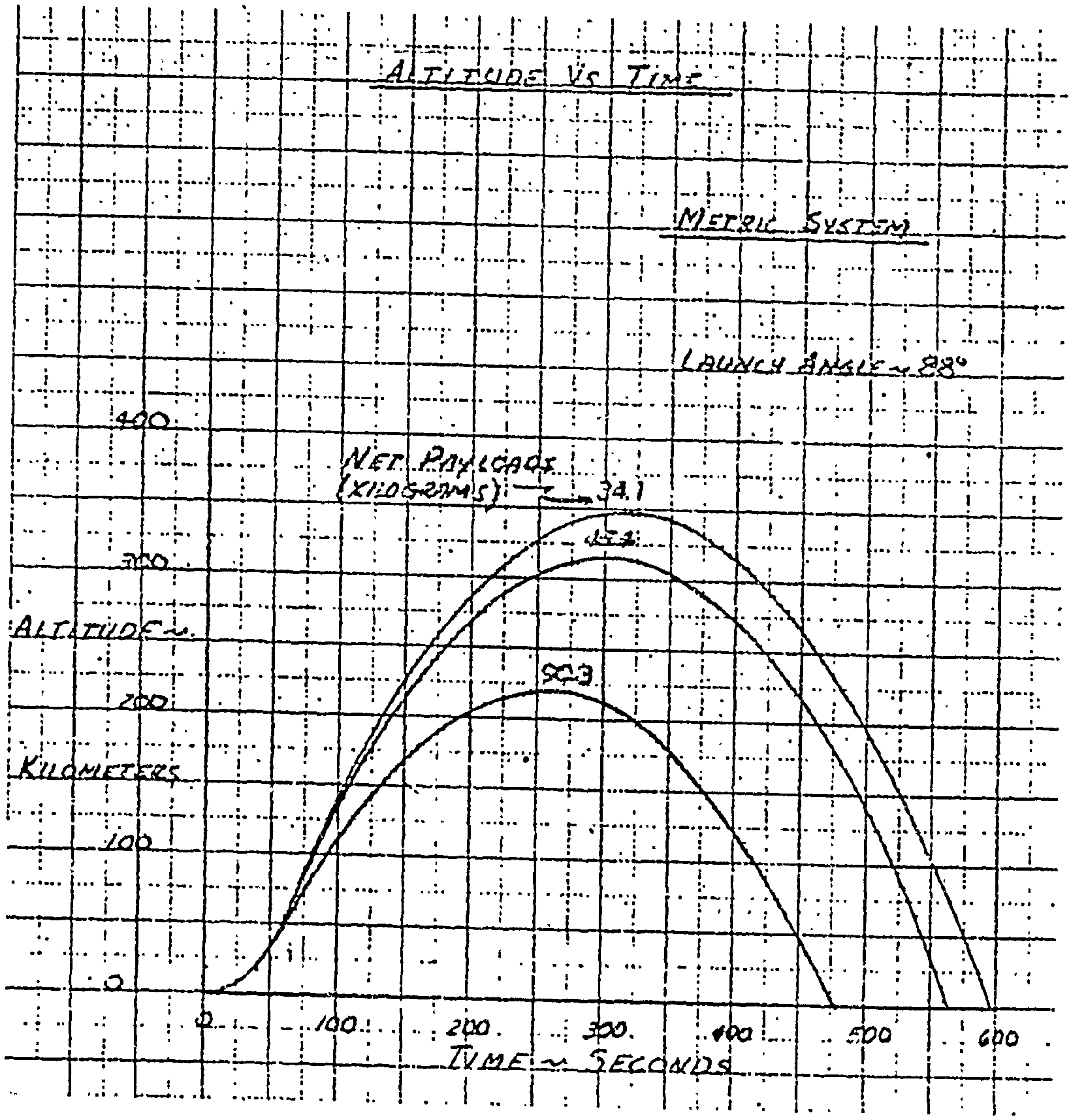

ALTITUDE VS TIME
METRIC SYSTEM
LAUNCH ANGLE ~ 88°
NET PAYLOADS (KILOGRAMS)
34.1
90.9
ALTITUDE ~ KILOMETERS
400
300
200
100
0
0
100
200
300
400
500
600
TIME ~ SECONDS

Fig. 21

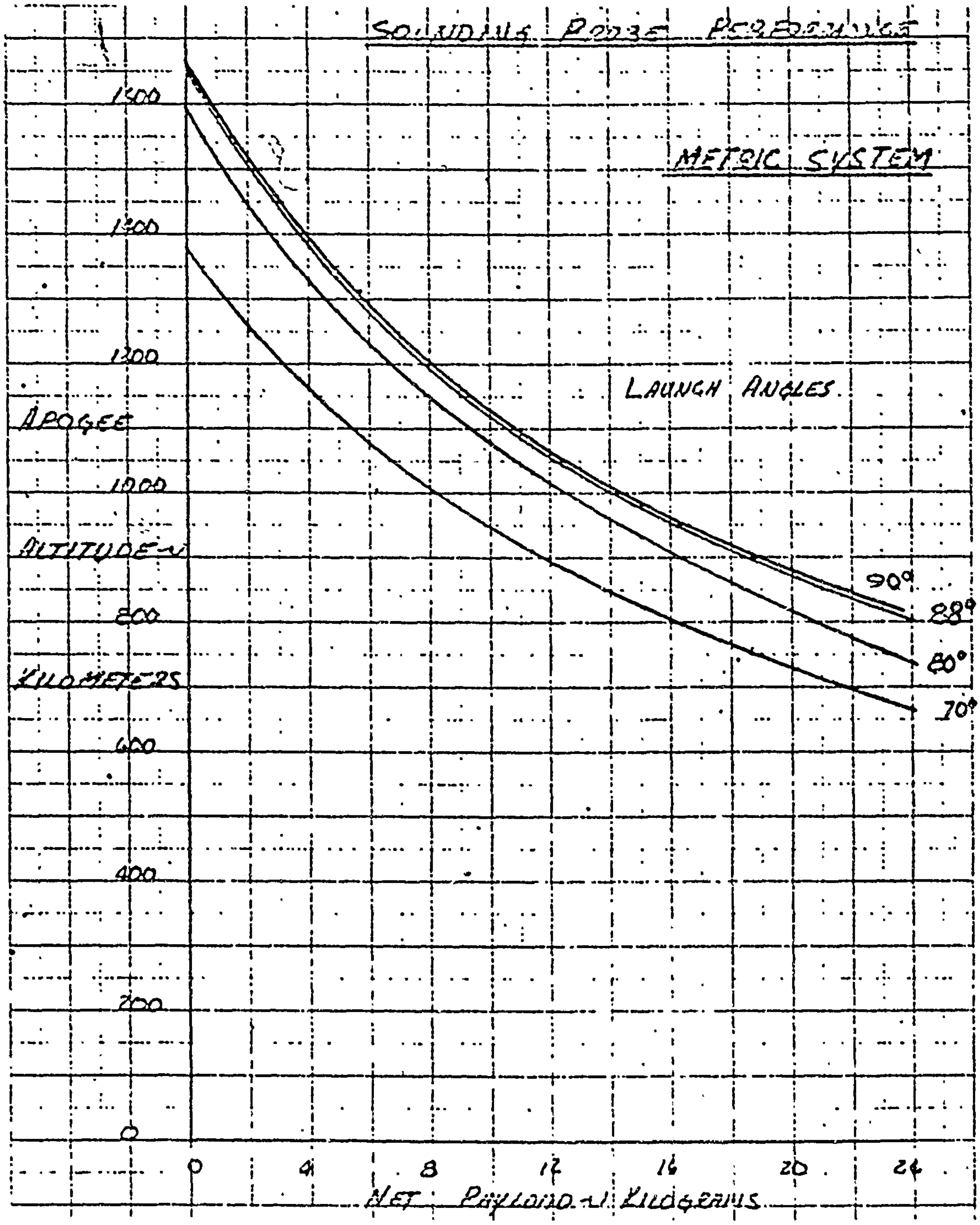

METRIC SYSTEM
LAUNCH ANGLES
1600
1400
1200
1000
800
600
400
200
0
APOGEE ALTITUDE ~ KILOMETERS
0
4
8
12
16
20
24
NET PAYLOAD ~ KILOGRAMS
90°
88°
80°
70°

Fig. 23

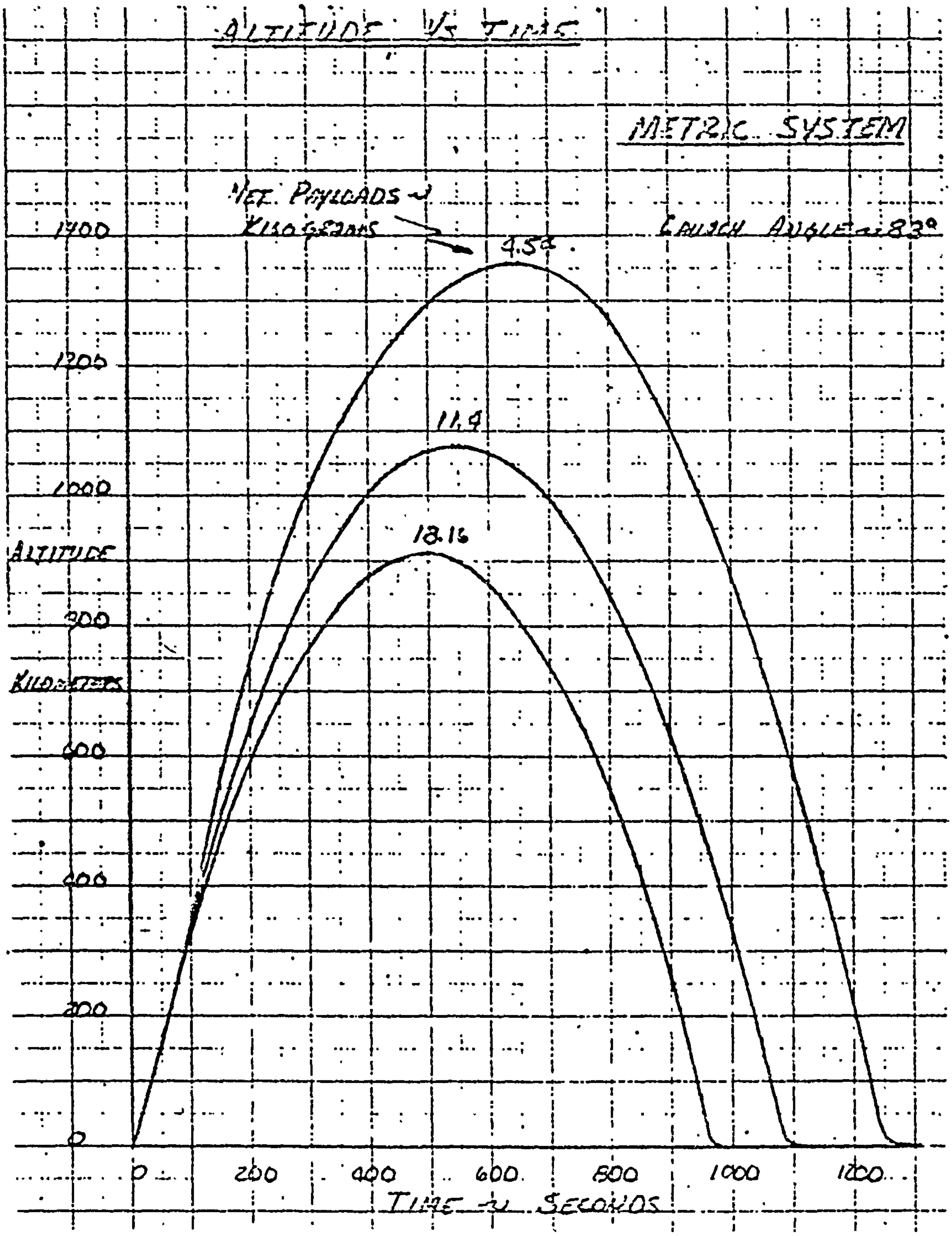

ALTITUDE VS TIME
METRIC SYSTEM
NET PAYLOADS ~ KILOGRAMS
LAUNCH ANGLE ~ 83°
4.53
11.4
18.16
ALTITUDE KILOMETERS
1400
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
TIME ~ SECONDS

Fig. 24

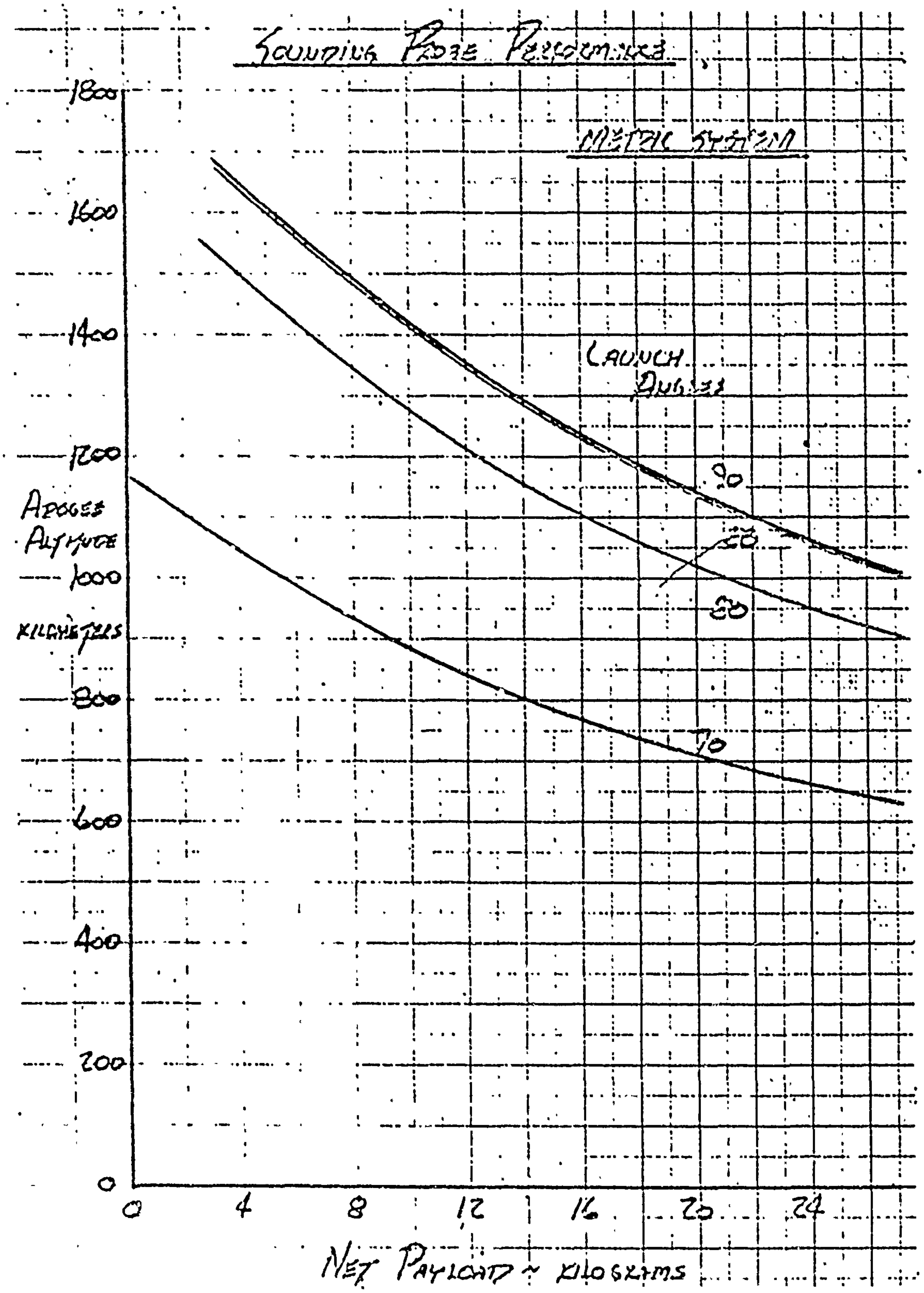
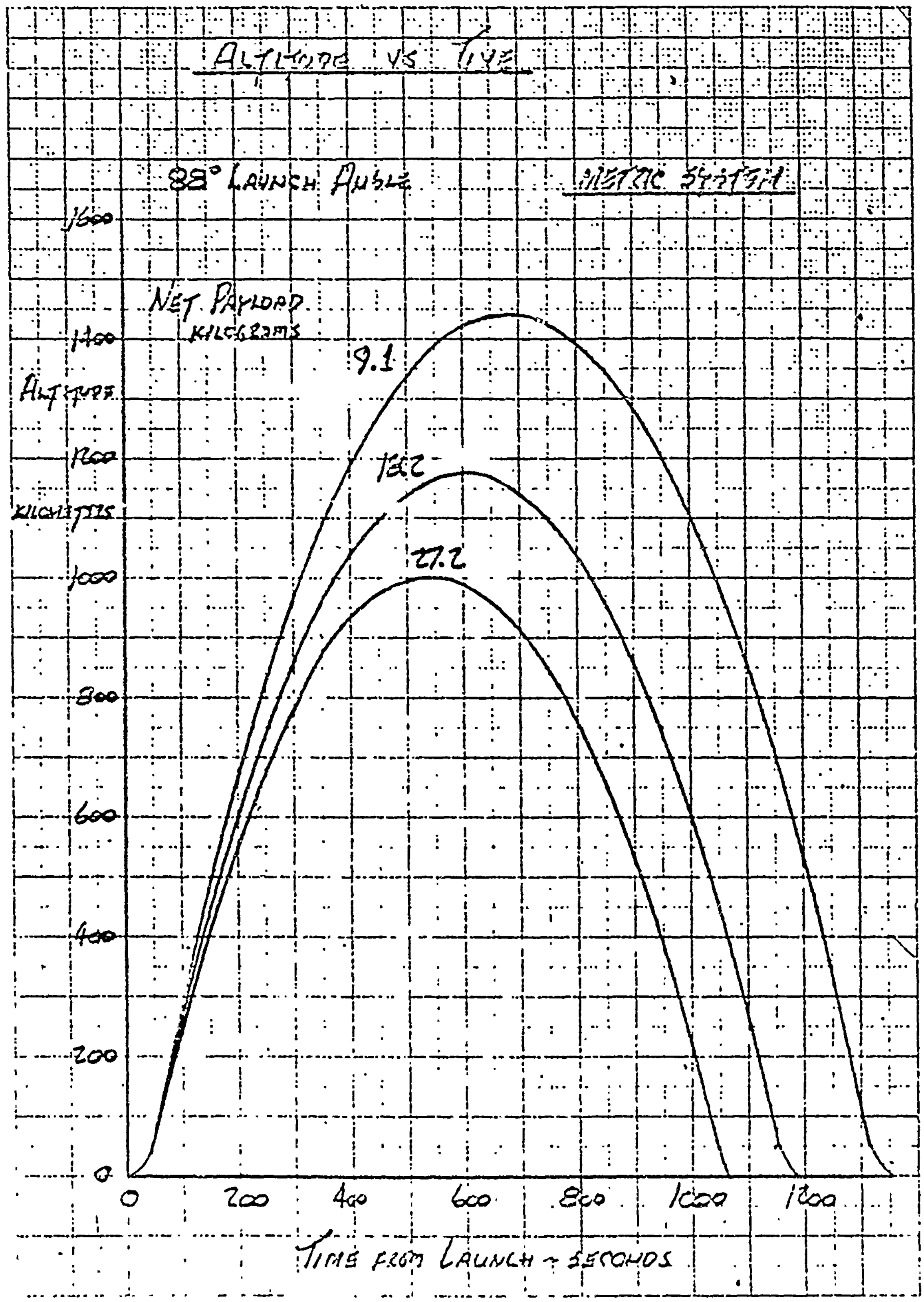

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
1800
1600
1400
1200
1000
800
600
400
200
0
APOGEE ALTITUDE KILOMETERS
LAUNCH ANGLES
90
80
80
70
0
4
8
12
16
20
24
NET PAYLOAD ~ KILOGRAMS

Fig. 26



ALTITUDE VS TIME
88° LAUNCH ANGLE
METRIC SYSTEM
NET PAYLOAD KILOGRAMS
9.1
18.2
27.2
ALTITUDE KILOMETERS
1600
1400
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
TIME FROM LAUNCH ~ SECONDS

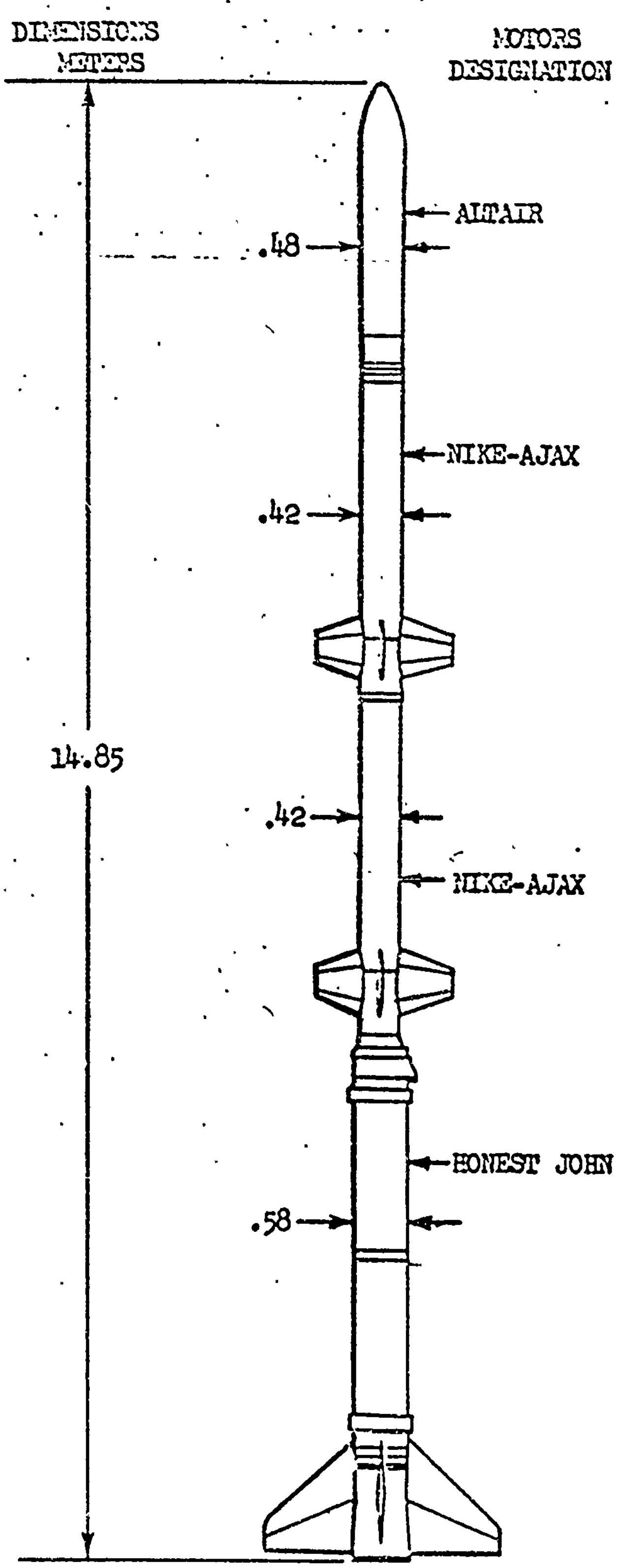
Fig. 27

11. JAVELIN

The Javelin, also known as the Argo D-4, is manufactured by the Aerolab Development Company under sponsorship of the National Aeronautics and Space Administration. Figure 28 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 29 shows the vehicle performance for various launch angles. Figure 30 shows a plot of altitude versus time for three payloads.

The Javelin has four steps, each using a solid propellant rocket motor. Roll and stabilization are accomplished by fins on the first, second and third step. The roll rate is approximately one, six, eleven and ten revolutions per second during burning of the first, second, third and fourth stages, respectively. A reduction in roll rate down to 2 revolutions per second occurs when the nose cone is ejected, soon after burnout of the last stage. The first and second steps drag separate after motor burnout. Separation of the third step is accomplished by a blow-out diaphragm which is ruptured at fourth stage ignition. A simple beam without a guide track is sufficient for launching the vehicle. There have been nine firings of which seven were successful. A budgetary recurring cost for a vehicle is 42,627 dollars in lots ten, not including the payload.

JAVELIN



1. Performance Weights Less Payload

LAUNCH	KILOGRAMS
Launch	3353.
B.O. 1st	2364.
Fire 2nd	1461.
B.O. 2nd	1114.
Fire 3rd	865.3
B.O. 3rd	518.8
Fire 4th	248.1
B.O. 4th	37.65

2. Payload Range
   34. to 80 Kilograms

3. Maximum Acceleration
   36 g's

Fig. 28

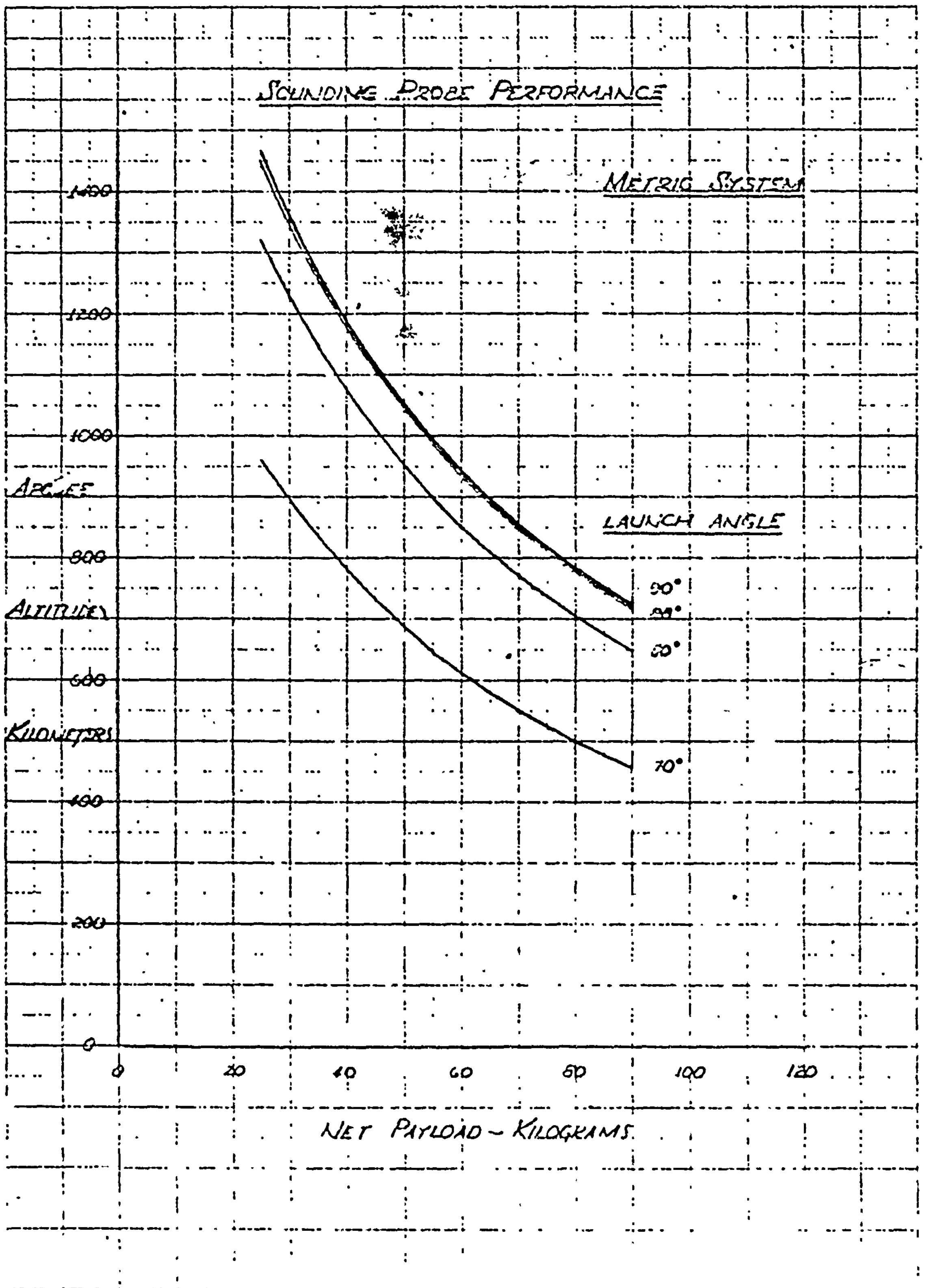

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
APOGEE ALTITUDE KILOMETERS
1400
1200
1000
800
600
400
200
0
LAUNCH ANGLE
90°
80°
80°
70°
0
20
40
60
80
100
120
NET PAYLOAD – KILOGRAMS

Fig. 29

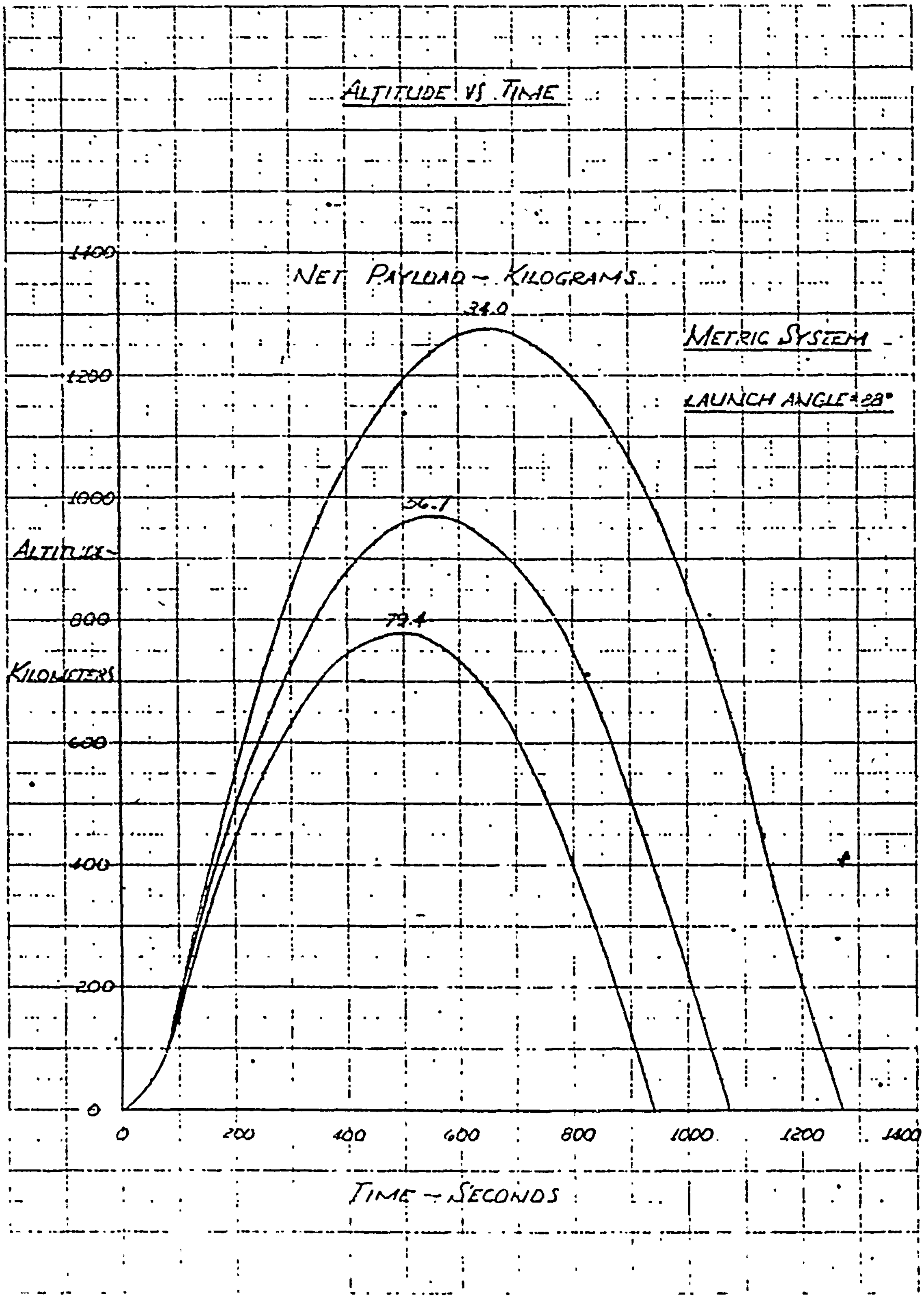

ALTITUDE VS TIME
NET PAYLOAD ~ KILOGRAMS
34.0
56.7
79.4
METRIC SYSTEM
LAUNCH ANGLE = 28°
ALTITUDE ~ KILOMETERS
0
200
400
600
800
1000
1200
1400
TIME ~ SECONDS

Fig. 30

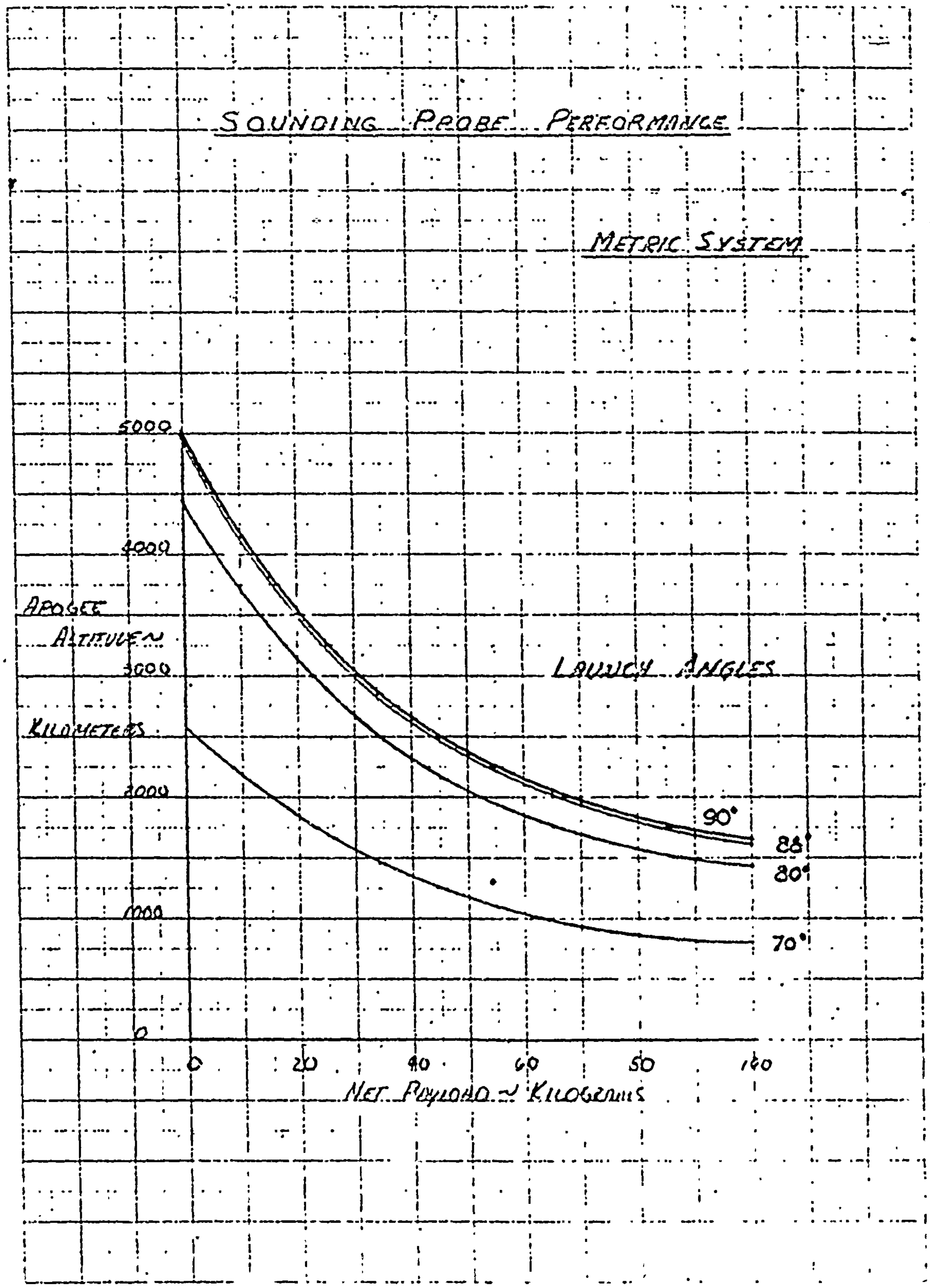

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
5000
4000
3000
2000
1000
0
APOGEE ALTITUDE ~ KILOMETERS
LAUNCH ANGLES
90°
88°
80°
70°
0
20
40
60
80
100
NET PAYLOAD ~ KILOGRAMS

Fig. 32

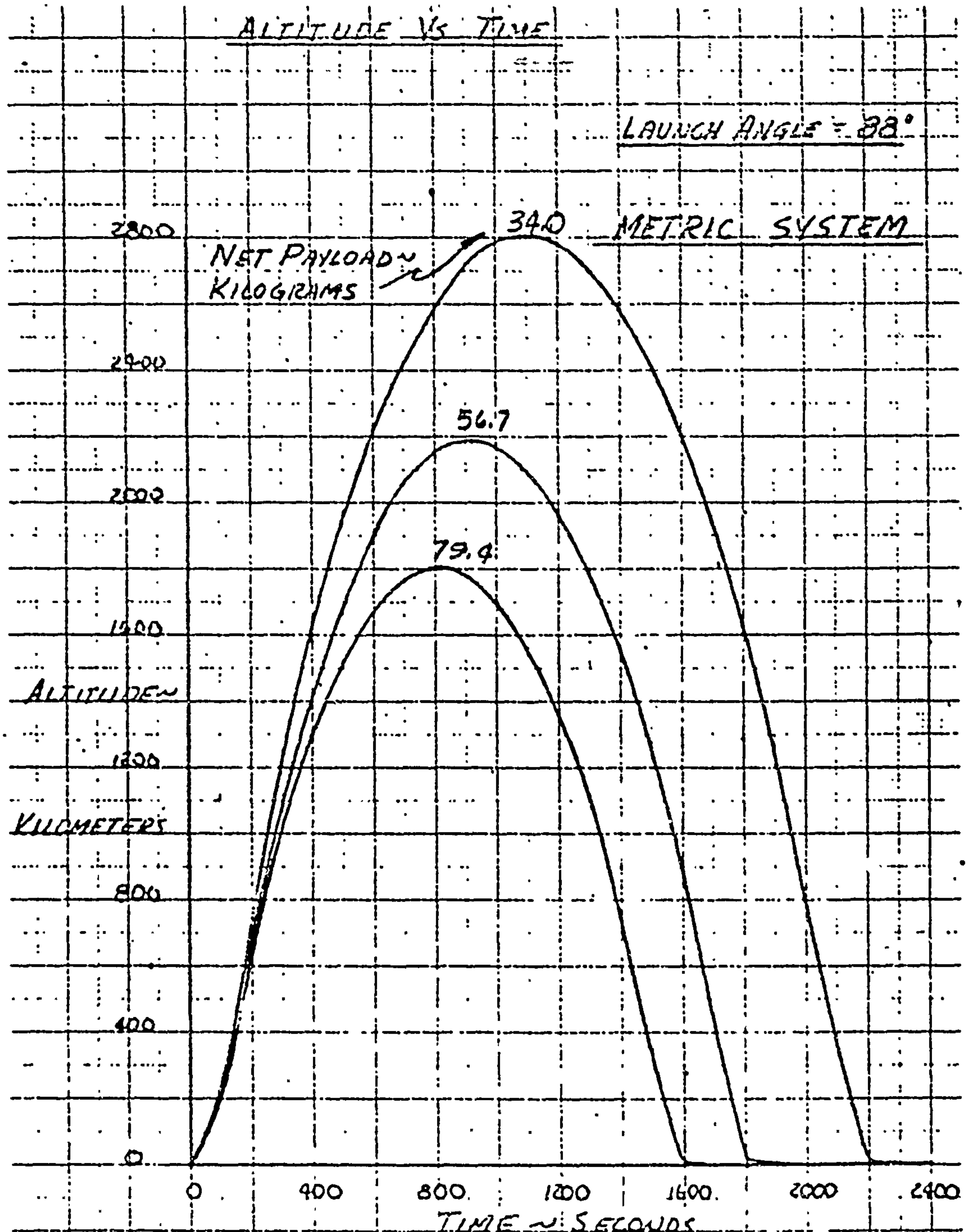

ALTITUDE VS TIME
LAUNCH ANGLE = 88°
340
METRIC SYSTEM
NET PAYLOAD ~
KILOGRAMS
56.7
79.4
2800
2400
2000
1600
1200
800
400
0
ALTITUDE ~
KILOMETERS
0
400
800
1200
1600
2000
2400
TIME ~ SECONDS

Fig. 33

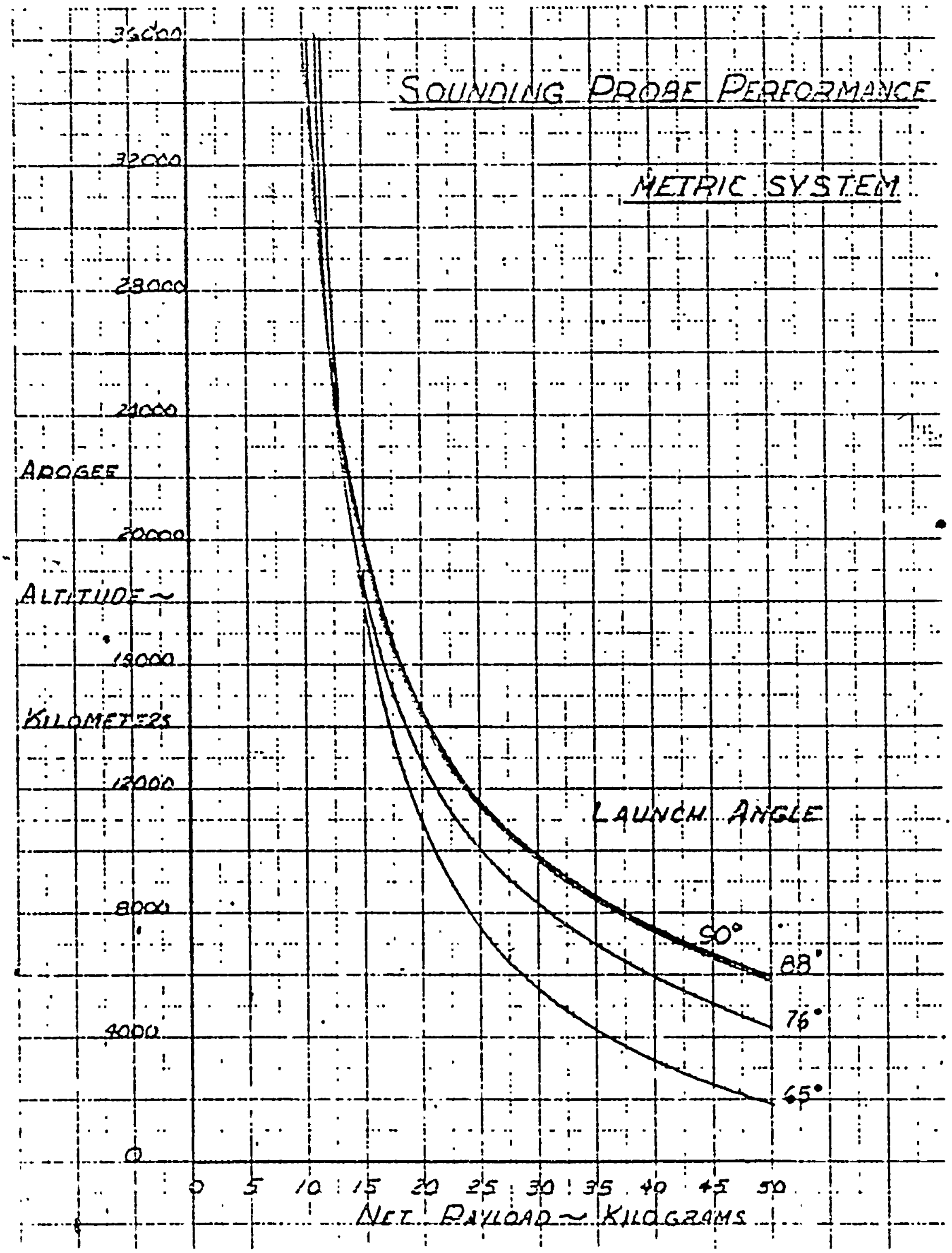

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
APOGEE
ALTITUDE ~
KILOMETERS
NET PAYLOAD ~ KILOGRAMS
LAUNCH ANGLE
90°
88°
76°
65°
0
4000
8000
12000
20000
24000
28000
32000
0
5
10
15
20
25
30
35
40
45
50

Fig. 35

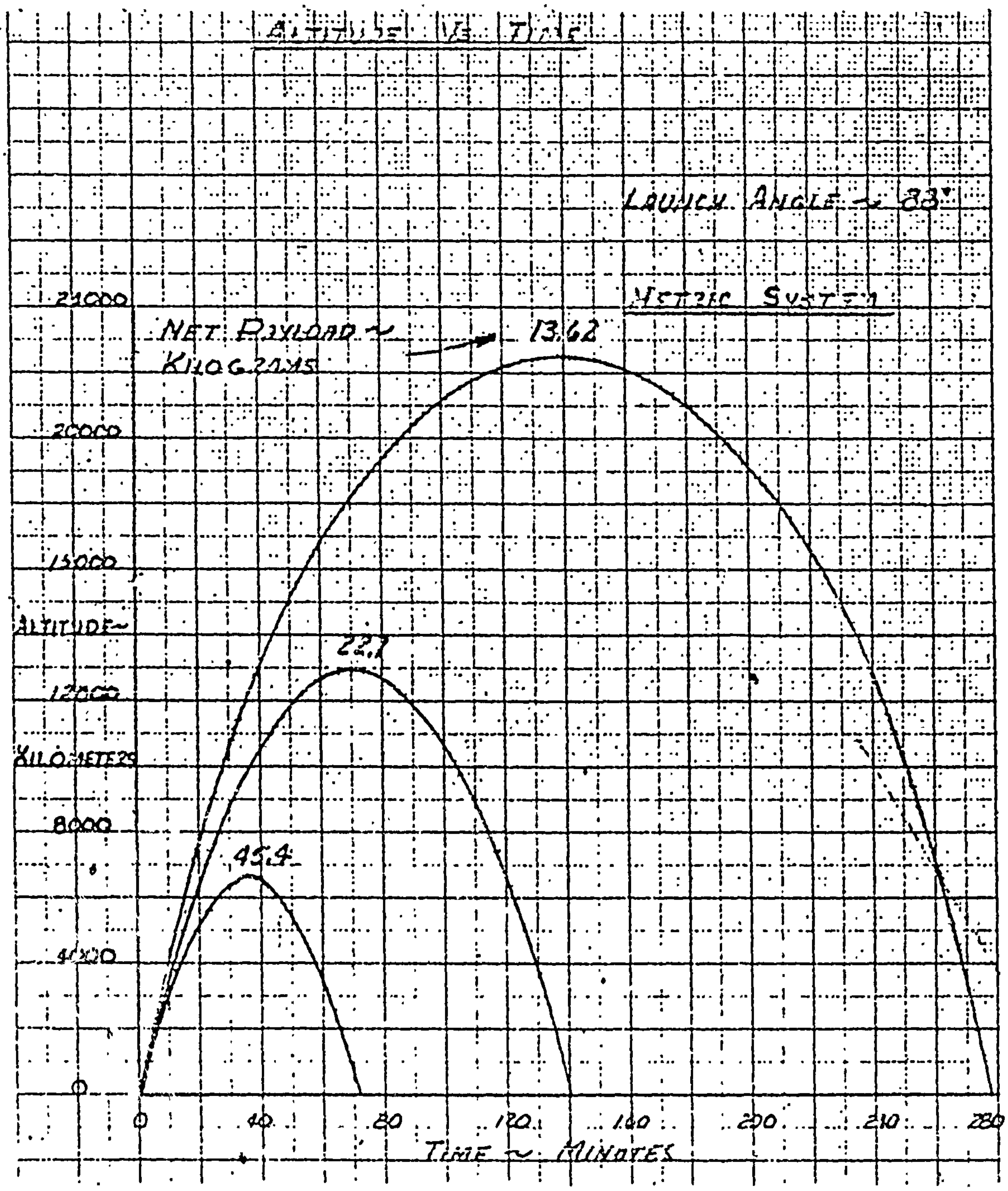

ALTITUDE VS TIME
LAUNCH ANGLE ~ 83°
METRIC SYSTEM
NET PAYLOAD ~ KILOGRAMS
13.62
22.7
45.4
ALTITUDE ~ KILOMETERS
24000
20000
16000
12000
8000
4000
0
TIME ~ MINUTES
0
40
80
120
160
200
240
280

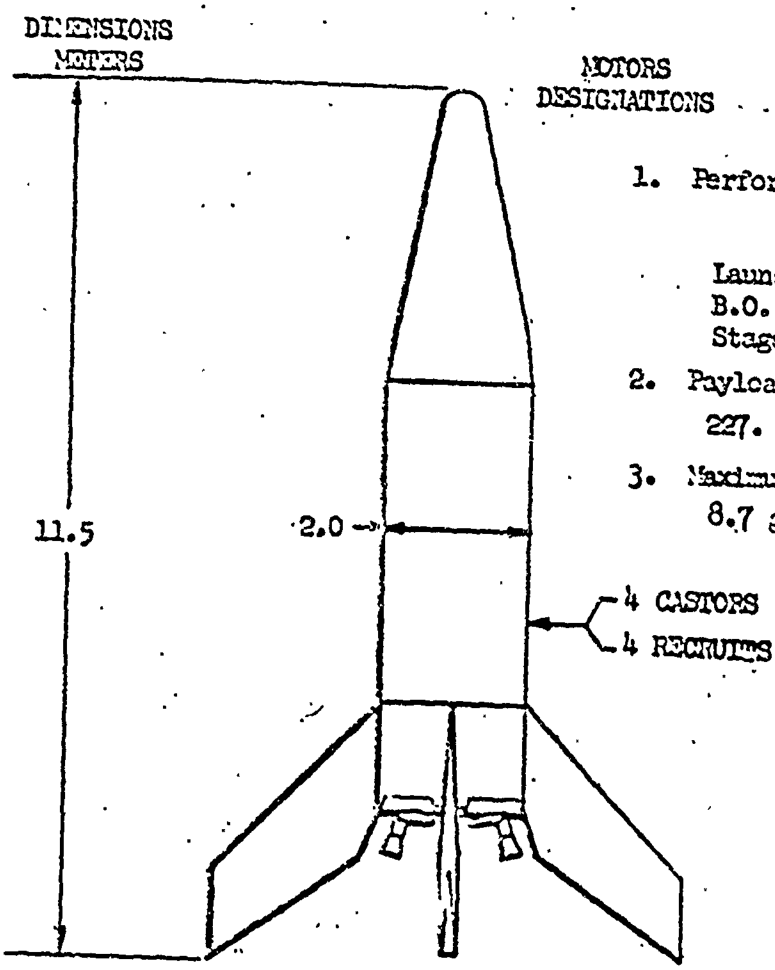
Fig. 36

14. LITTLE JOE

The Little Joe was manufactured by the Missile Division of North American Aviation, Inc. under contract to the National Aeronautics and Space Administration in connection with a research and development program in support of Project Mercury. Figure 37 shows a sketch of the vehicle, staging weights, payload-weight range, and maximum acceleration. Figure 38 shows the vehicle performance for various launch angles. Figure 39 shows a plot of altitude versus time for three payloads.

The Little Joe has four stabilization fins and eight solid propellant rocket motors which remain as a unit during flight. The vehicle is unguided. Two of the main motors and the four auxiliary, short burning, motors are fired initially. The other two main motors are fired during the final burning of the first two main motors. The nominal roll rate is zero for this vehicle. The launcher provides four support points at the base of the vehicle plus a zero-length type support at the forward end of the vehicle. This forward support swings clear of the vehicle at take-off. The Little Joe was designed for the purpose of propelling full scale models of the Mercury capsule and escape system to supersonic speeds at low altitudes for the objective of proof testing the escape system at high dynamic pressure. It also demonstrated high altitude capability during a test where essentially zero dynamic pressure was required. The manned capsule configuration has, therefore, been replaced by a simple nose cone suitable for the majority of research experiments and is reflected in the performance calculations. A budgetary recurring cost for a vehicle, excluding a nose cone and payload, is 335,000 dollars in lots of ten.

LITTLE JOE



1. Performance Weights Less Payload

	Kilograms
Launch	18633.
B.O. 1st Stage	4720.4

2. Payload Range

   227. to 1361. Kilograms

3. Maximum Acceleration

   8.7 g's

Fig. 37

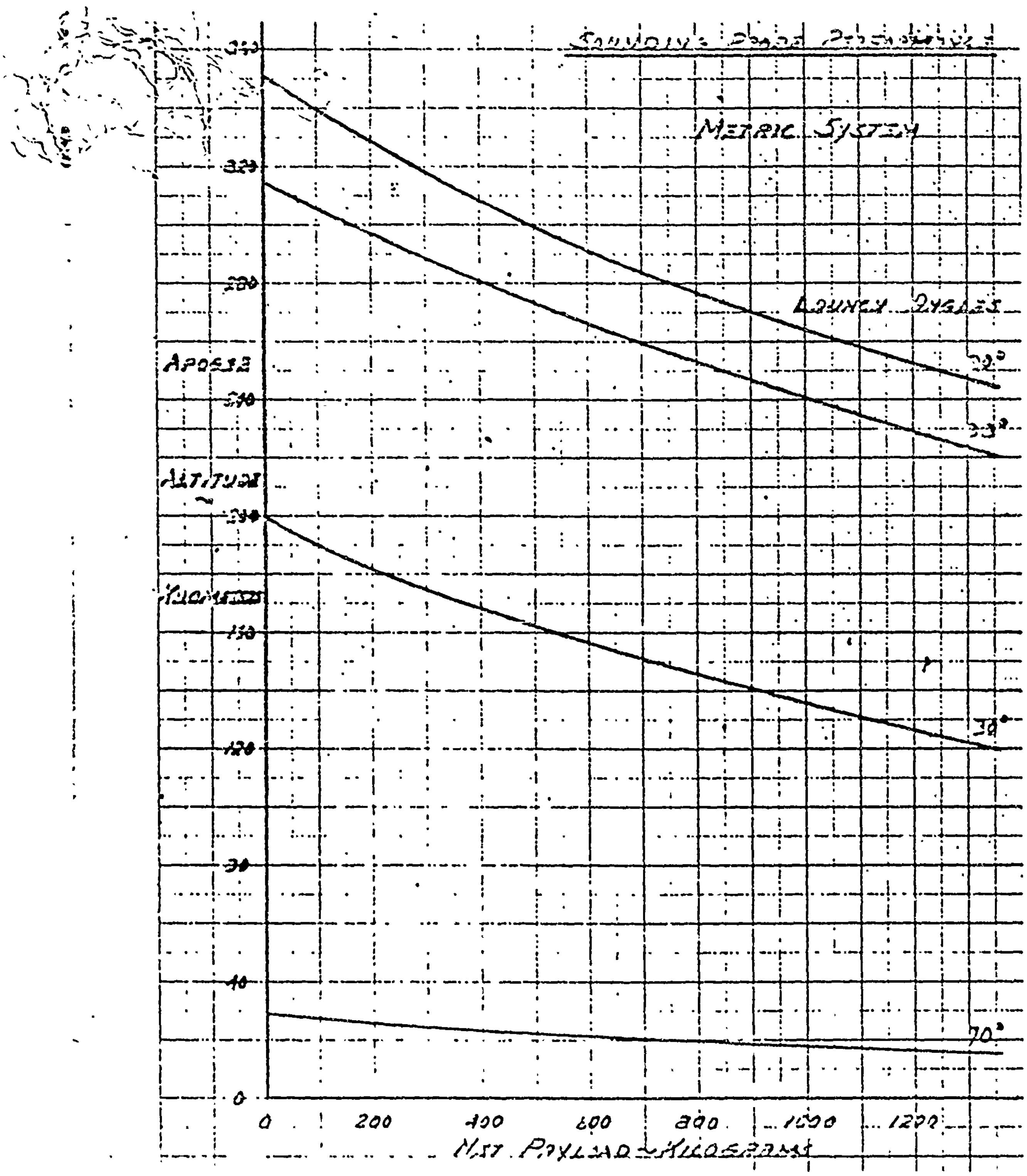


Fig. 33

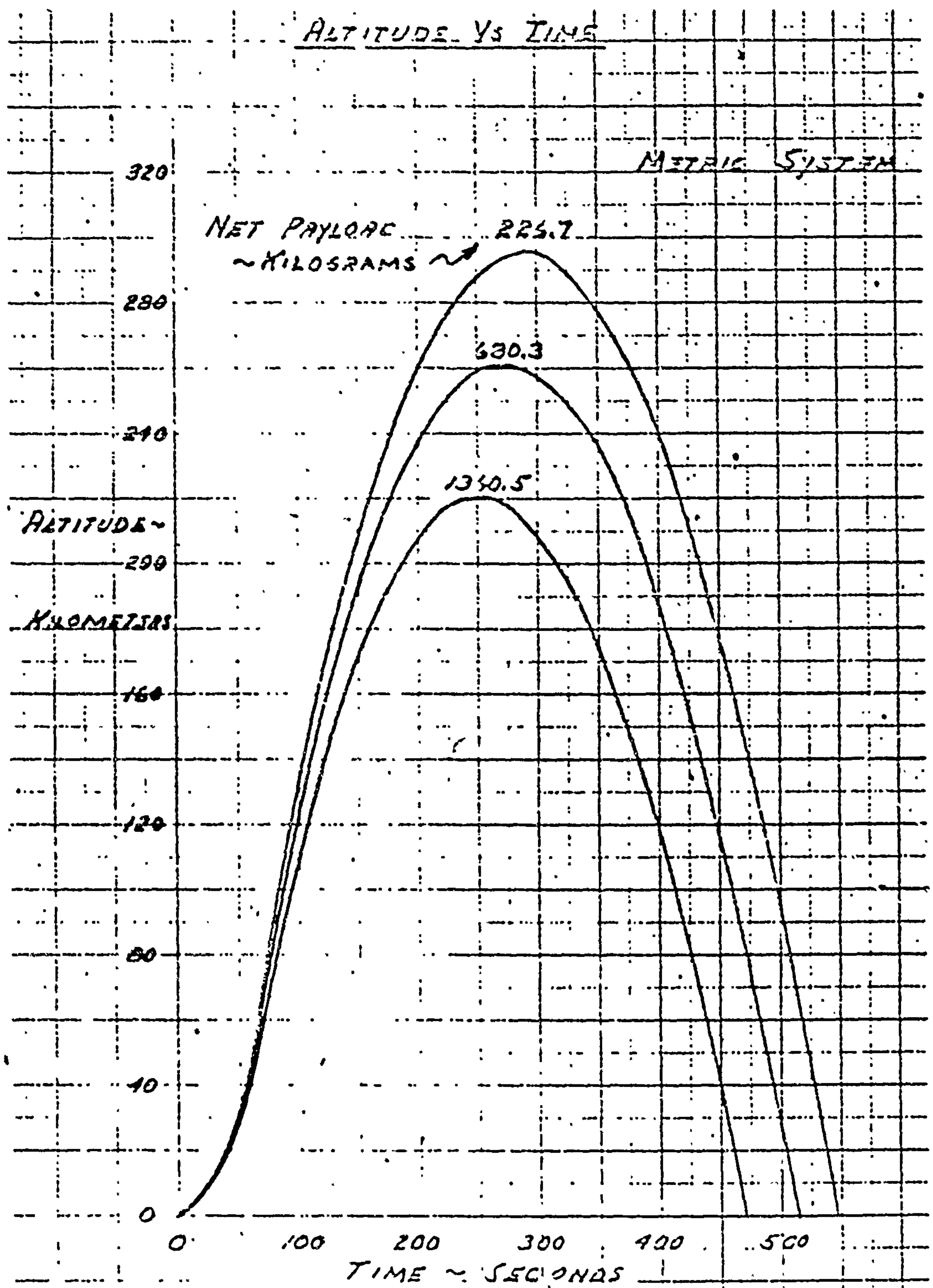

ALTITUDE VS TIME
METRIC SYSTEM
NET PAYLOAD ~KILOGRAMS
225.7
630.3
1350.5
ALTITUDE ~ KILOMETERS
320
280
240
200
160
120
80
40
0
0
100
200
300
400
500
TIME ~ SECONDS

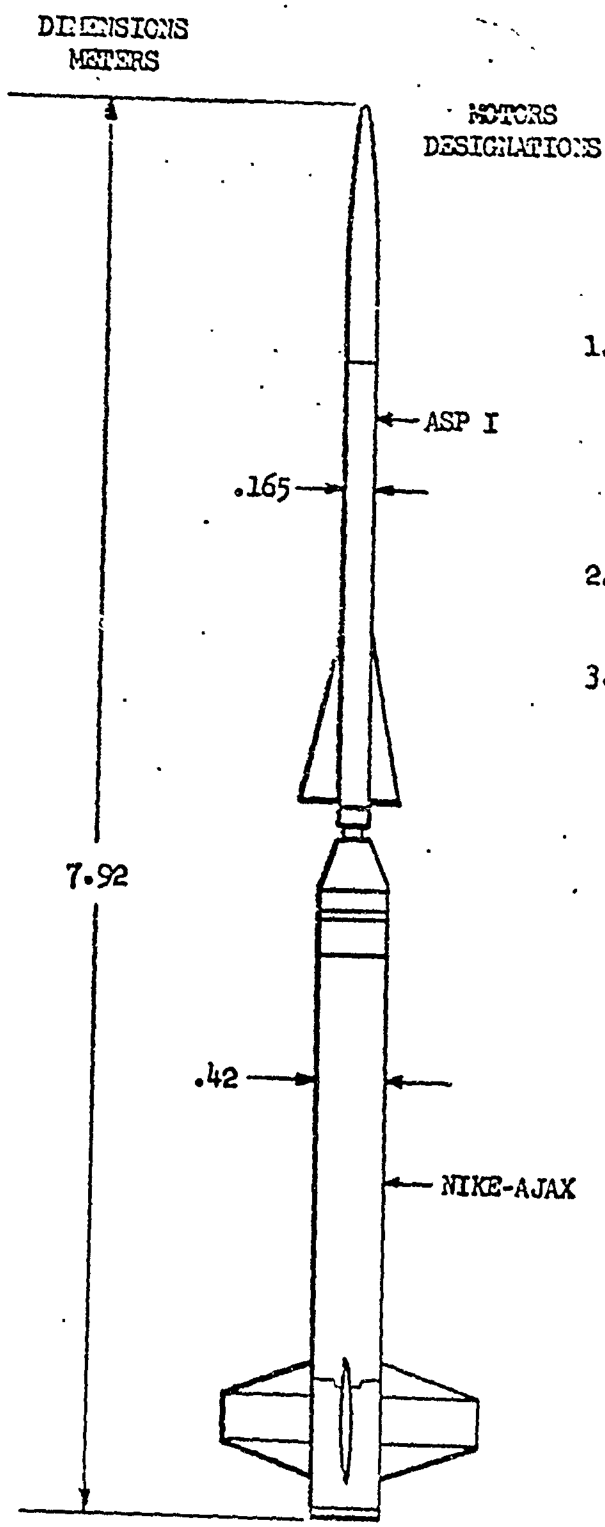
Fig. 39

13. NIKE-ASP

The Nike-Asp, also known as the Aspan 150, is manufactured by Cooper Development, a Division of the Marquardt Corporation. Figure 40 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 41 shows the vehicle performance for various launch angles. Figure 42 shows a plot of altitude versus time for three payloads.

The Nike-Asp has two steps, each utilizing one solid propellant rocket motor. Stabilization fins are attached to both steps. Spin tabs are positioned on the fin so as to impart an approximate spin rate of 2.5 revolutions per second for the first stage and 4.5 revolutions per second for the second stage. After burnout of the first stage, separation is accomplished by rupturing a connector ring by an explosive charge set off by a squib which gets its signal from either a sensor or ground command. The second stage then coasts until an atmospheric pressure sensitive firing circuit ignites the final motor. The Nike-Asp can be fired from a simple beam launcher and does not require a guide rail. The vehicle was fired from White Sands, New Mexico; San Nicolas Island, California; and shipboard during the International Geophysical Year. Additional firings have taken place at Wallops Island, Virginia and Eglin Air Force Base, Florida. A total of 67 firings have been made of which 40 were successful. A budgetary recurring cost for a vehicle is 14,831 dollars in lots of 10, not including the payload.

NIKE-ASP



1. Performance Weights Less Payload

	Kilograms
Launch	700.0
B.O. 1st Stage	353.4
Fire 2nd Stage	104.4
B.O. 2nd Stage	37.5

2. Payload Range

   11 to 46. Kilograms

3. Maximum Acceleration

   49 g's

Fig. 40

NIKE-ASP

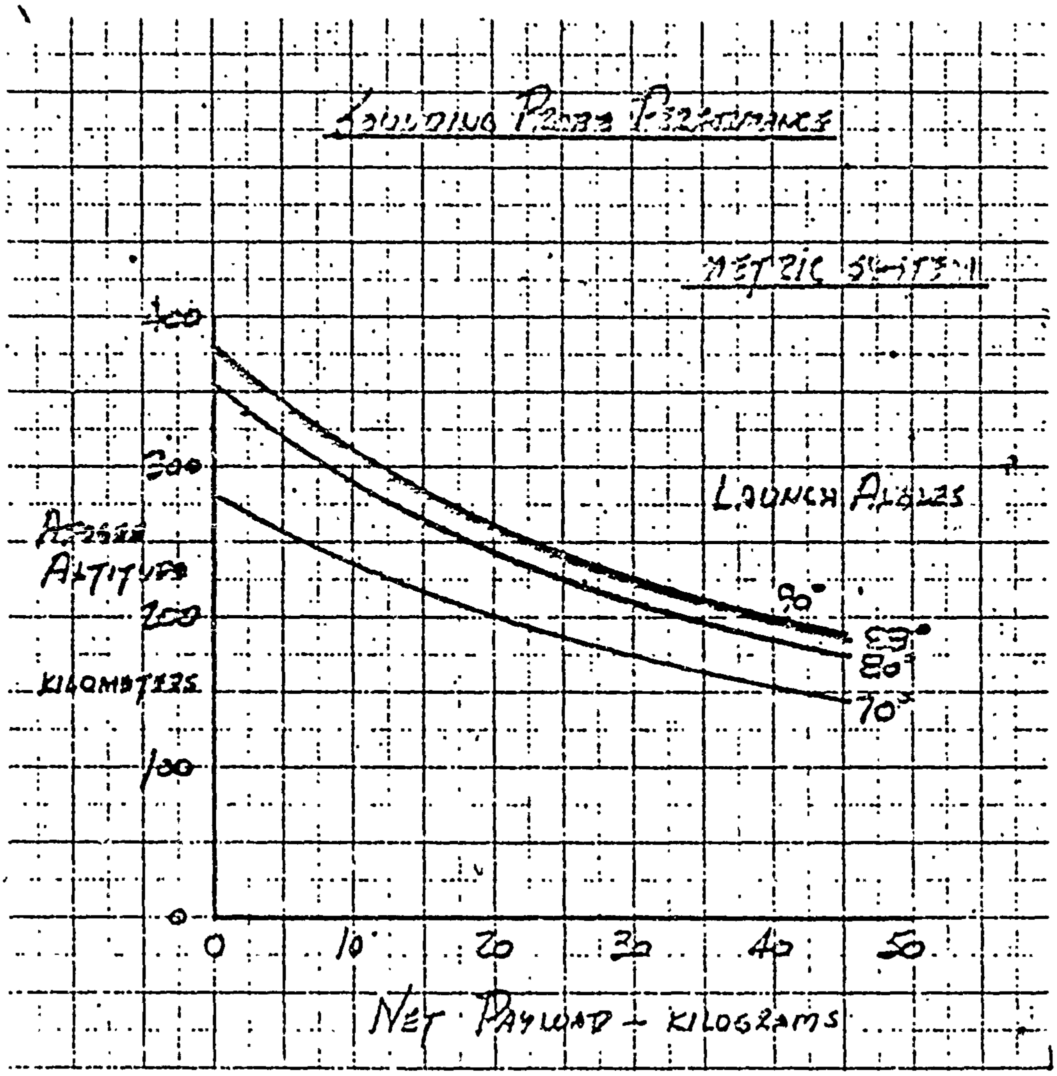


Fig. 41

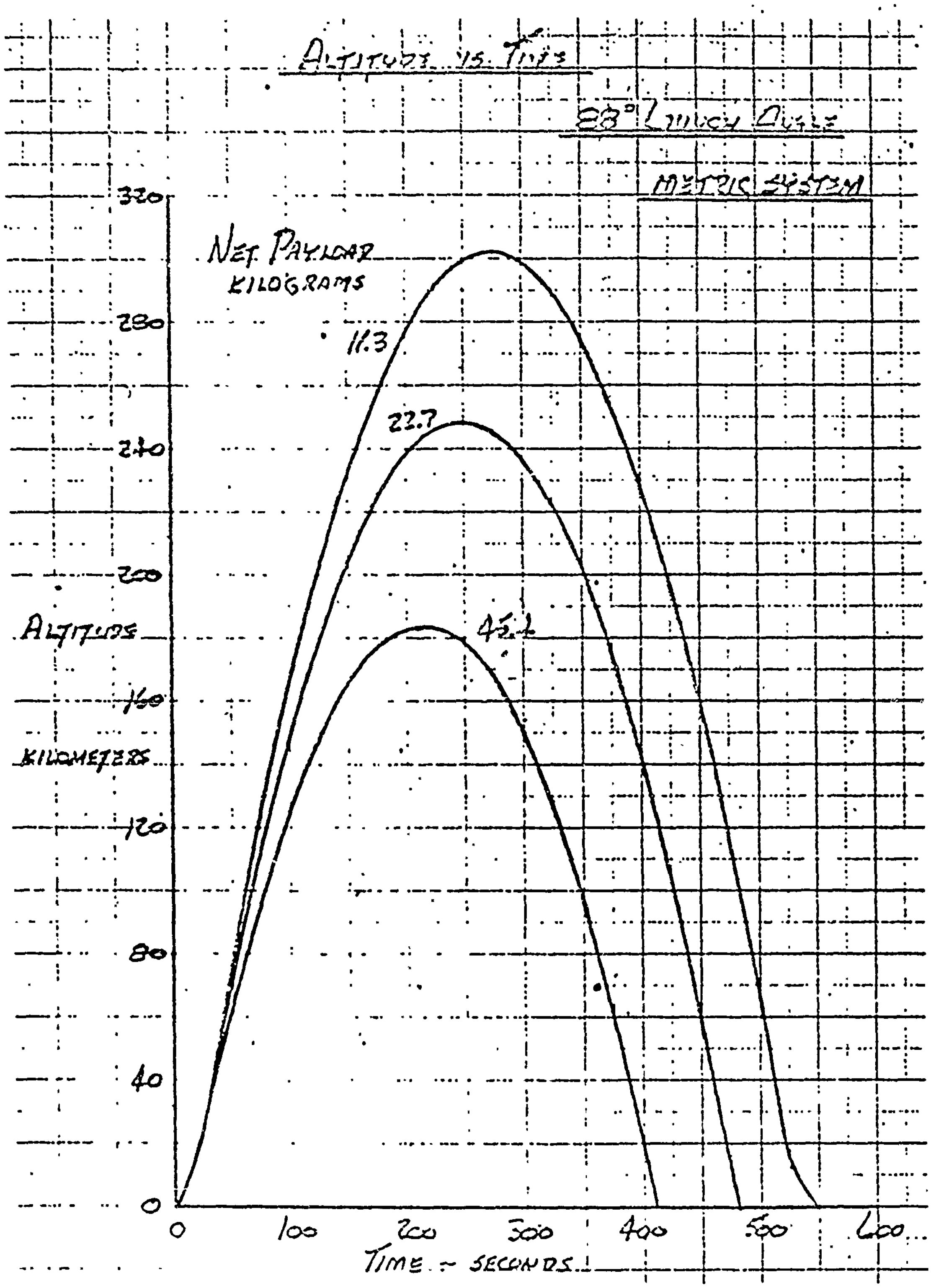

ALTITUDE VS. TIME
83° LAUNCH ANGLE
METRIC SYSTEM
NET PAYLOAD KILOGRAMS
11.3
22.7
45.4
ALTITUDE KILOMETERS
320
280
240
200
160
120
80
40
0
0
100
200
300
400
500
600
TIME ~ SECONDS

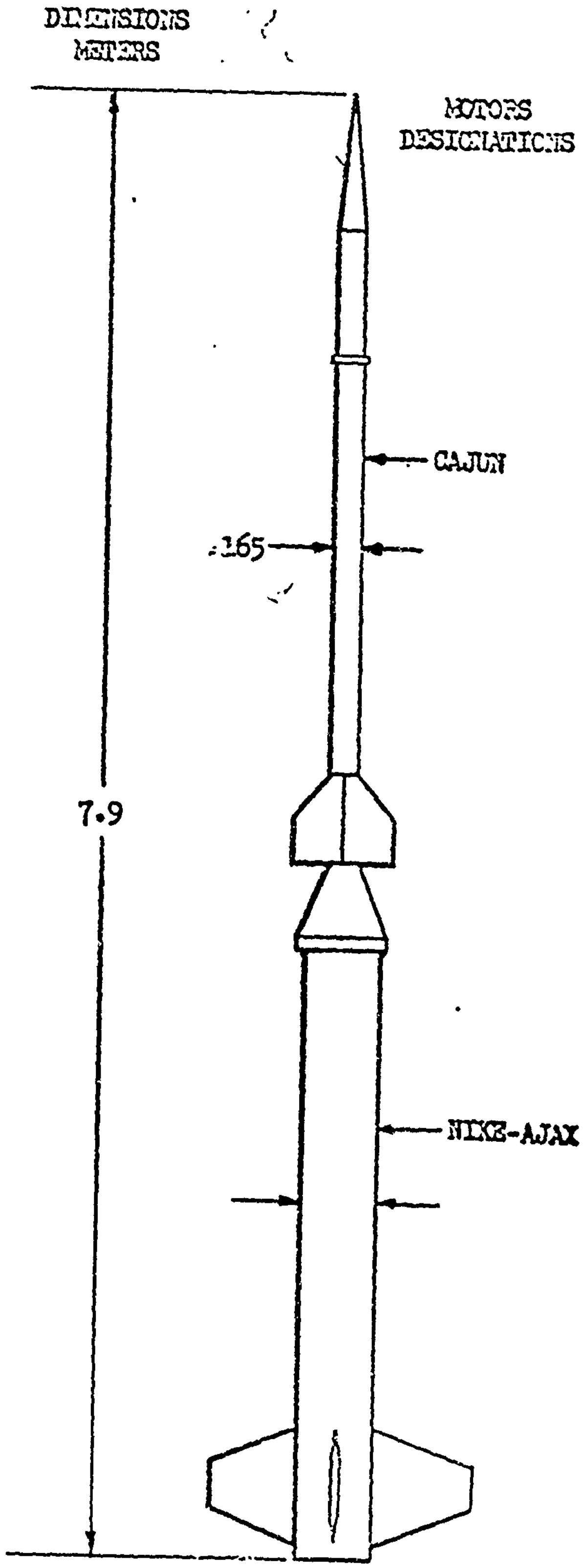
Fig. 42

18. NIKE-CAJUN

The Nike-Cajun is manufactured by the University of Michigan under the sponsorship of the Air Force Cambridge Research Center and the National Aeronautics and Space Administration. Figure 43 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 44 shows the vehicle performance for various launch angles. Figure 45 shows a plot of altitude versus time for three payloads.

The Nike-Cajun has two steps, each utilizing one solid propellant rocket motor. Stabilization fins are attached to both steps. The nominal roll rate for the vehicle is zero. The first step motor is ground-fired and at burnout the step drag separates. The second stage ignites at some prescribed ignition delay time depending upon the pyrotechnic delay squib employed. The squib is ignited at launch. The Nike-Cajun can be fired from a simple beam launcher and does not require a guide rail. The vehicle was fired from Fort Churchill, Canada; White Sands, New Mexico; Guam, Mariana Islands; Wallops Island, Virginia; and shipboard during the International Geophysical Year. Additional firings have taken place from Elgin Air Force Base, Florida and Wallops Island, Virginia. The first Nike-Cajun was successfully flown in July of 1956 and since then there have been over 80 additional flights with a vehicle success record of approximately 90%. A budgetary recurring cost for a vehicle is 5,000 dollars in lots of 10, not including the payload.

NIKE-CAJUN



1. Performance Weights Less Payload

	Kilograms
Launch	689.0
B.O.1st	342.4
Fire 2	98.4
B.O. 2	44.2

2. Payload Range

   11. to 46. Kilograms

3. Maximum Acceleration

   62 g's

Fig. 13

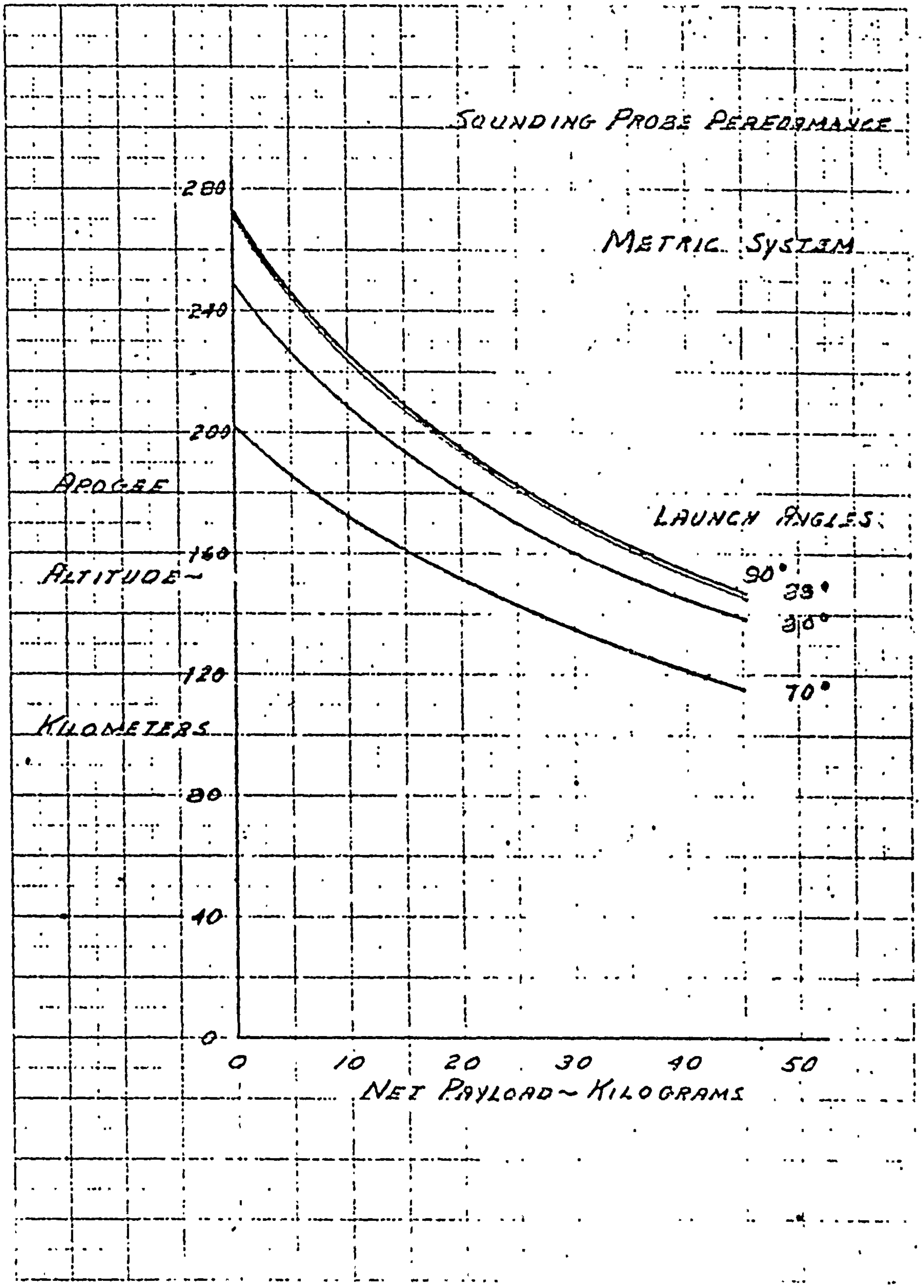

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
APOGEE
ALTITUDE ~
KILOMETERS
280
240
200
160
120
80
40
0
LAUNCH ANGLES:
90°
85°
80°
70°
0
10
20
30
40
50
NET PAYLOAD ~ KILOGRAMS

Fig. 44

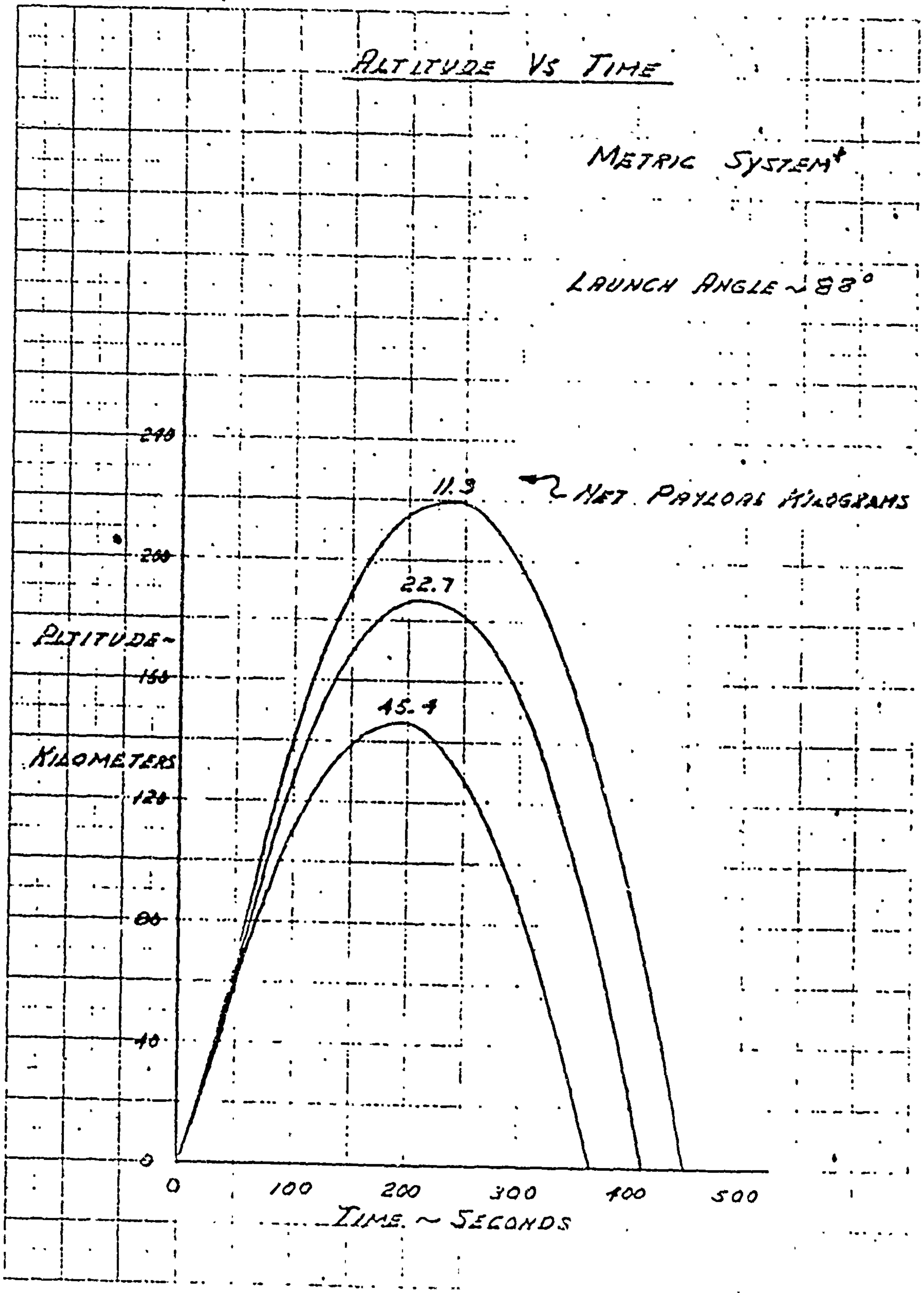

ALTITUDE VS TIME
METRIC SYSTEM*
LAUNCH ANGLE ~ 88°
11.3
NET PAYLOAD KILOGRAMS
22.7
45.4
ALTITUDE ~ KILOMETERS
240
200
160
120
80
40
0
0
100
200
300
400
500
TIME ~ SECONDS

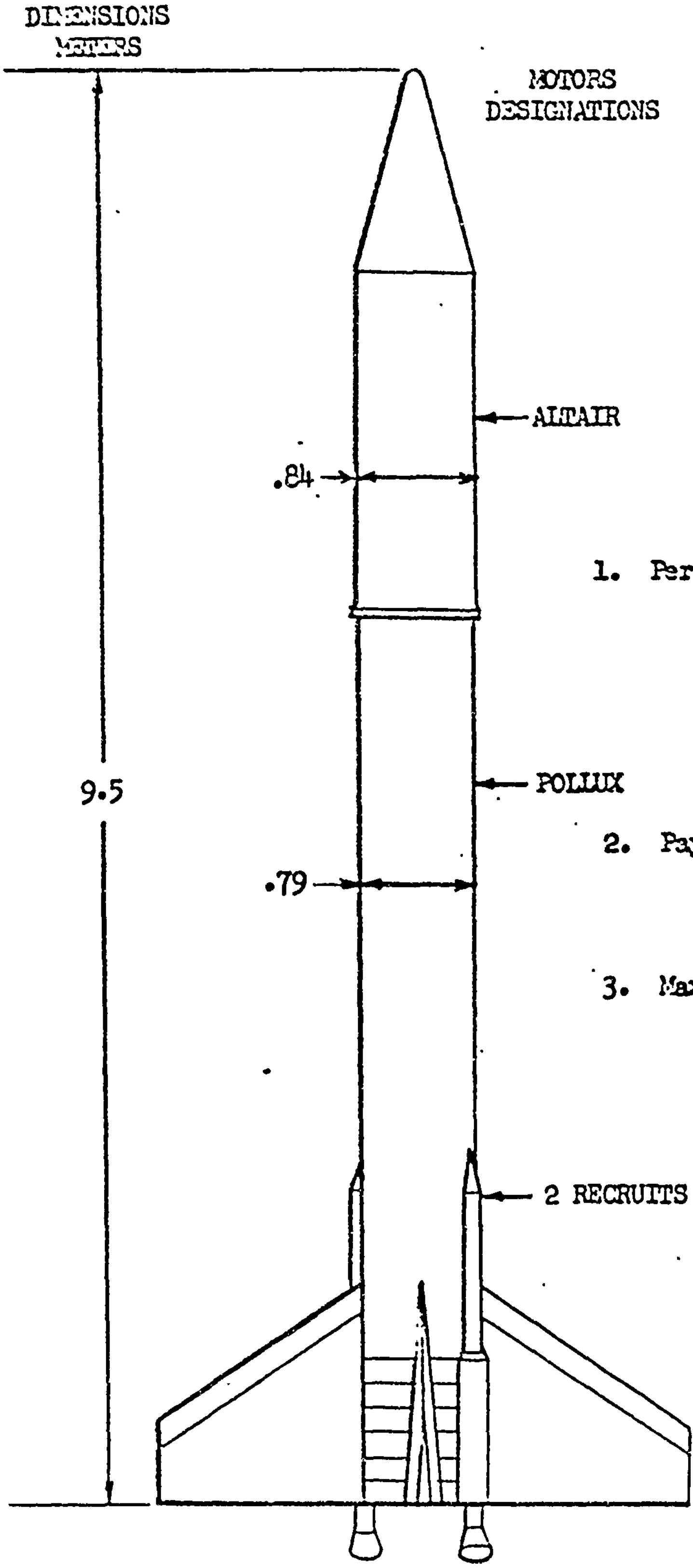
Fig. 15

17. SHOTPUT

The Shotput was developed by the National Aeronautics and Space Administration at the Langley Research Center, Virginia, to lift and eject a 30.5 meter diameter inflatable sphere at suborbital speeds. Figure 46 shows a sketch of the vehicle, Staging weights, payload weight range, and maximum acceleration. Figure 47 shows the vehicle performance for various launch angles. Figure 48 shows a plot of altitude versus time for three payloads.

The Shotput has two steps and utilizes all solid propellant rocket motors. The first step has one main motor plus two short burning auxiliary motors whose nozzles are canted through the take-off center of gravity of the vehicle. First step fins are used for stability and are canted to impart spin to the vehicle. The vehicle passes through roll resonance at about 15 seconds after take-off. After burnout of the first step main motor the vehicle coasts for approximateoy 42 seconds at which time the nose fairing is ejected. Two and one half seconds later the second stage is initially de-spun. Step separation is accomplished by releasing a ring clamp. The second step motor is then fired and at burnout the payload is further de-spun; retro-rockets separate the empty motor case from the payload. The vehicle can be fired from a simple beam launcher, with no guide rail required. The shotput has been fired five times from Wallops Island, Virginia. On one vehicle the second stage did not ignite; all the other four were successful. A budgetary recurring cost for a vehicle is 106, 207 dollars in lots of 10, not including the payload.

SECRET



1. Performance Weights Less Payload

	Kilograms
Launch	4980.
B.O. 1st Stage	1523.
Fire 2nd Stage	311.6
B.O. 2nd Stage	101.1

2. Payload Range

34. to 182. Kilograms

3. Maximum Acceleration

10 g's

Fig. 46

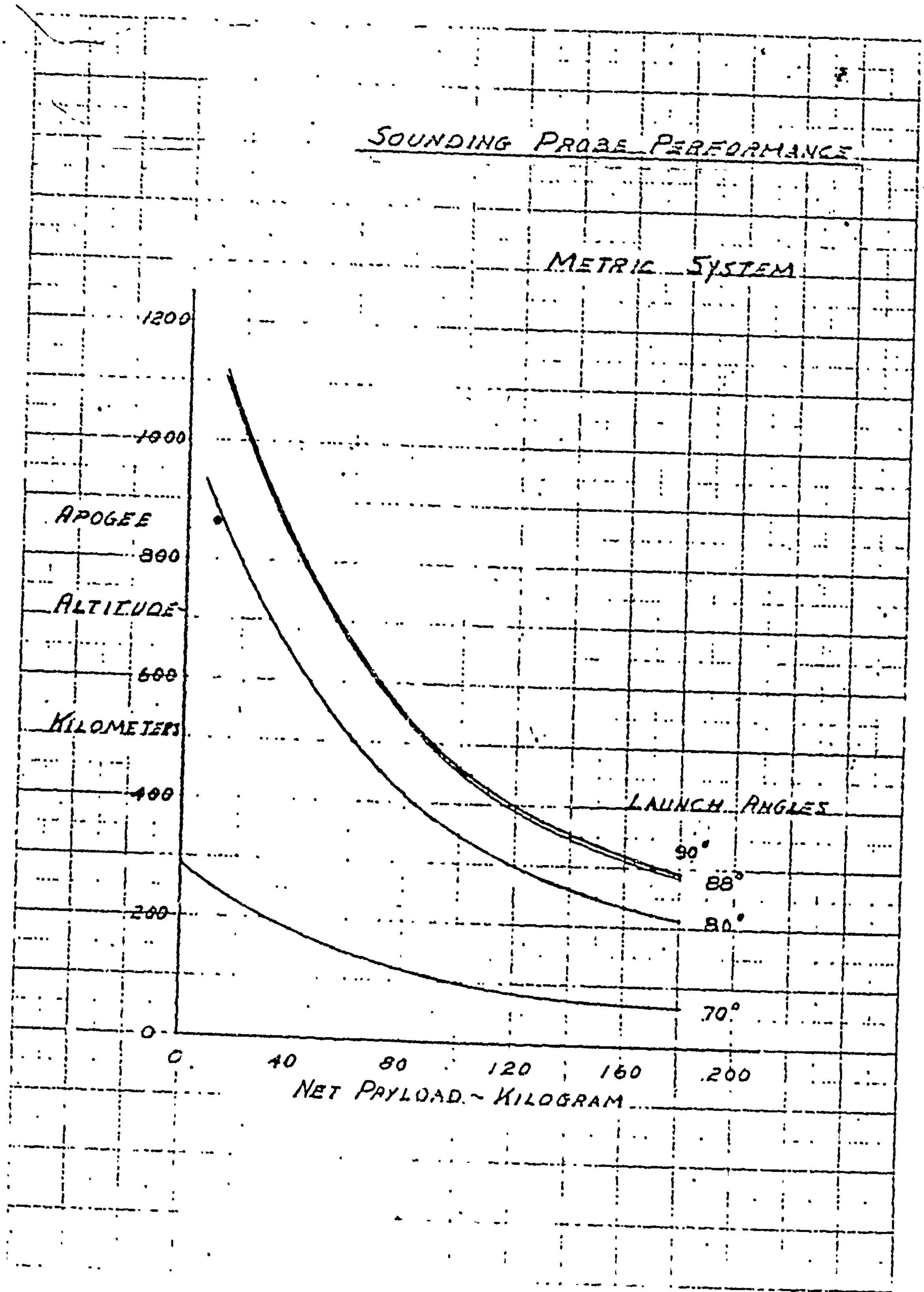

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
APOGEE
ALTITUDE
KILOMETERS
1200
1000
800
600
400
200
0
0
40
80
120
160
200
NET PAYLOAD ~ KILOGRAM
LAUNCH ANGLES
90°
88°
80°
70°

Fig. 17

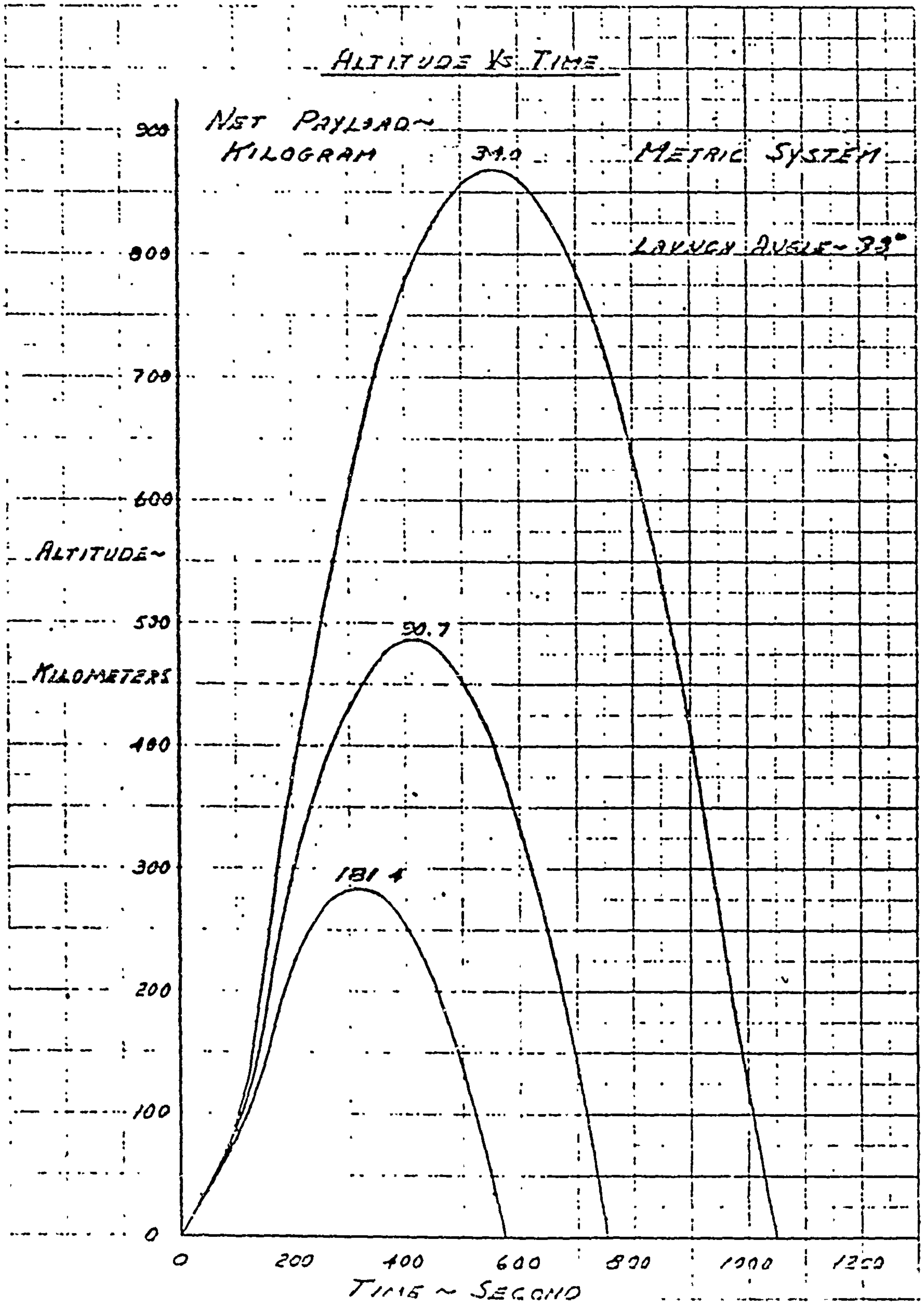
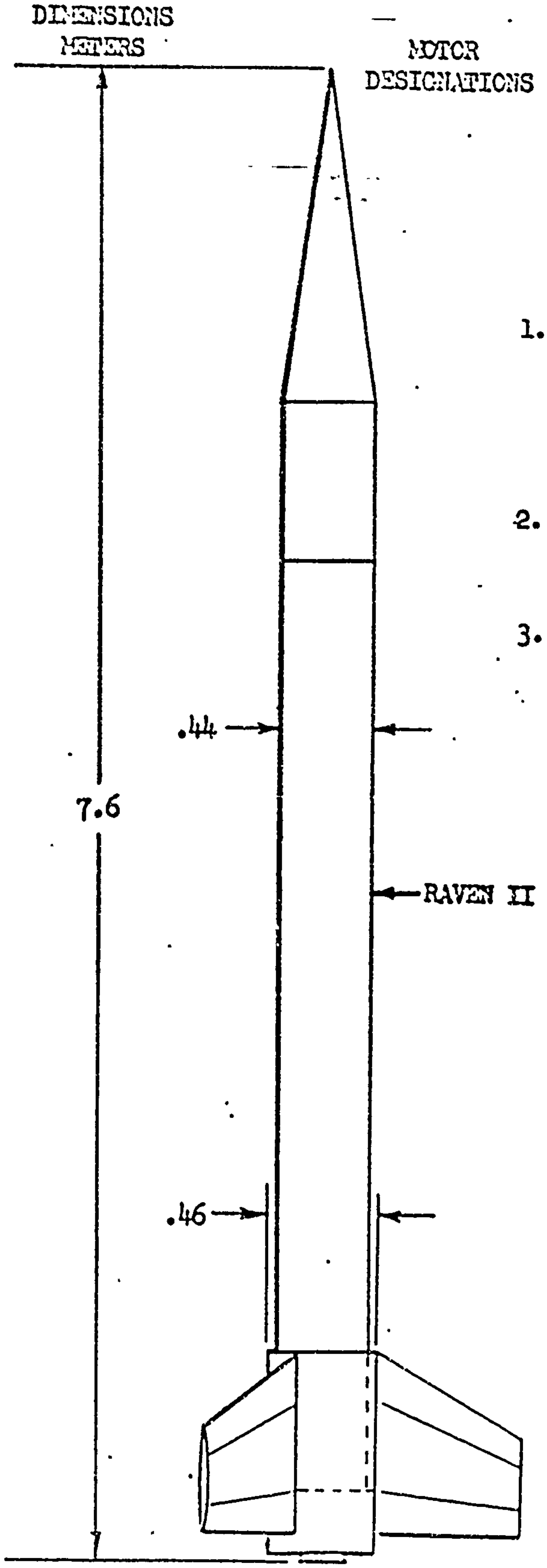

ALTITUDE VS TIME
NET PAYLOAD ~ KILOGRAM
METRIC SYSTEM
LAUNCH ANGLE ~ 33°
ALTITUDE ~ KILOMETERS
TIME ~ SECOND
181.4
90.7
34.0
0
100
200
300
400
500
600
700
800
900
0
200
400
600
800
1000
1200

Fig. 48

18. SKYLARK

The Skylark was developed in Great Britain for use in the research program of the Royal Aircraft Establishment. Figure 49 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 50 shows the vehicle performance for various launch angles. Figure 51 shows a plot of altitude versus time for three payloads. The Skylark uses one solid propellant rocket motor and has three fins spaced 120 degrees apart on the aft section for stabilization. The vehicle is unguided. During the six trial flights at Woomera, Australia, four variations in the basic motor were tried and two different fin configurations. The Raven II motor flown in Flight 05 was used in this study and also GW-25 fins, which were not used until subsequent flights. This motor has the highest initial thrust and maximum total impulse. The GW-25 fins are light-weight and low drag as compared to those used in the initial firings. The roll rate for the Skylark is nominally zero, but experience with this vehicle has shown that a random roll rate of about a half revolution per second can be expected. The launcher tower located at Woomera is 30.5 meters high and has three parallel guide rails. The tower can be moved by remote control through + 15 degrees to - 5 degrees in elevation, and ± 10 degrees in azimuth. In the six trial firings between February, 1957 and May 1958, all were successful from a vehicle standpoint. In two subsequent flights using GW-25 fins it was fairly well established that pitch-roll resonance occurred which greatly reduced the peak altitude on one and was catastrophic on the other. Improvements in fin construction, tolerance and alignment are expected to reduce the likelihood of this phenomenon. Seventeen Skylarks have been flown as of December, 1960. A small tandem booster motor called Cuckoo was developed for Skylark and adds some 64 kilometers to the peak altitude. A fully assembled vehicle with payload ready for firing costs approximately 30,000 dollars.

SKYLARK



1. Performance Weights Less Payload

	Kilograms
Launch	1104.
B.O.1st Stage	273.5

2. Payload Range
   22. to 114. Kilograms

3. Maximum Acceleration
   10 g's

Fig. 19

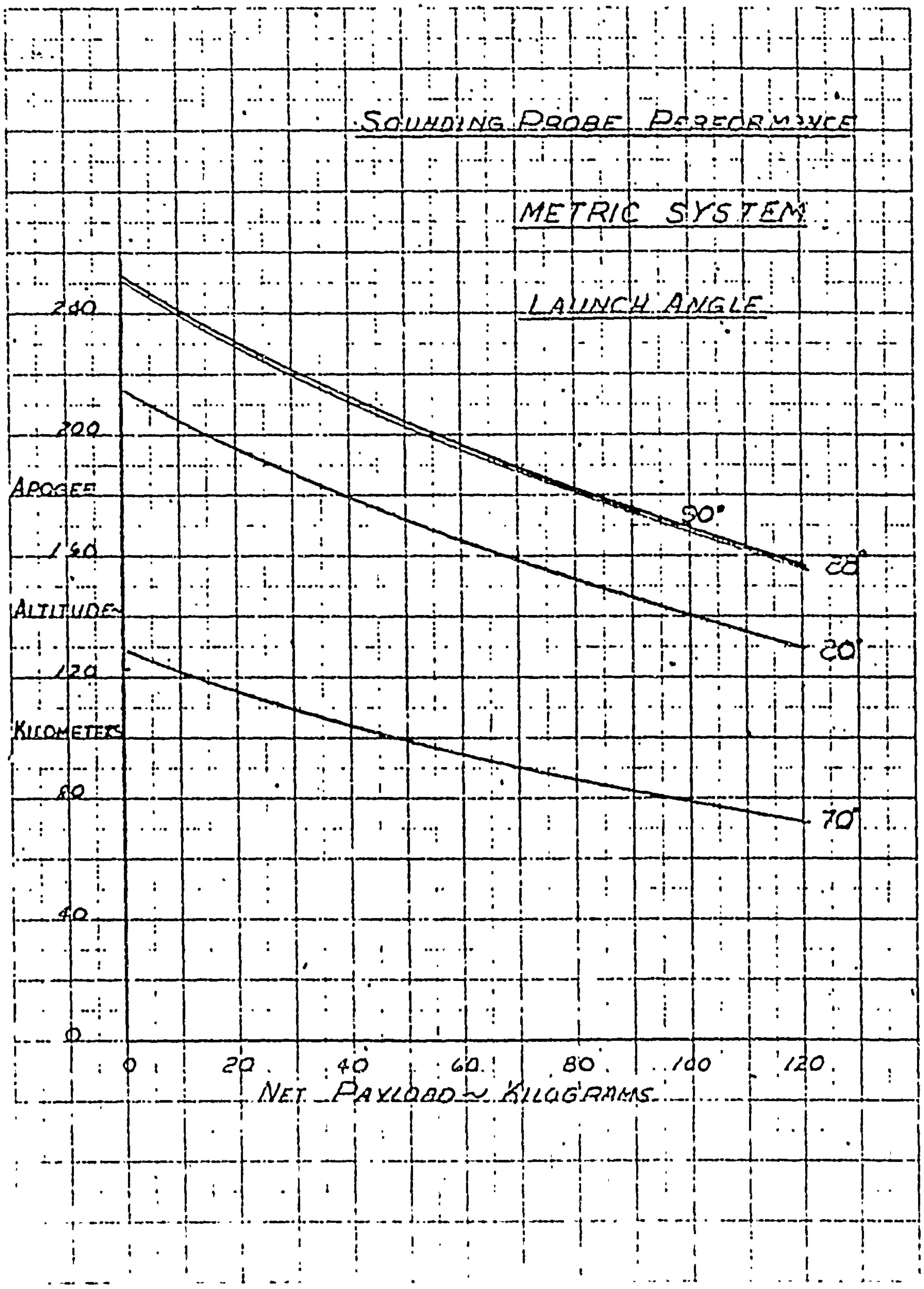

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
LAUNCH ANGLE
APOGEE ALTITUDE ~ KILOMETERS
240
200
160
120
80
40
0
90°
80°
20°
70°
0
20
40
60
80
100
120
NET PAYLOAD ~ KILOGRAMS

Fig. 50

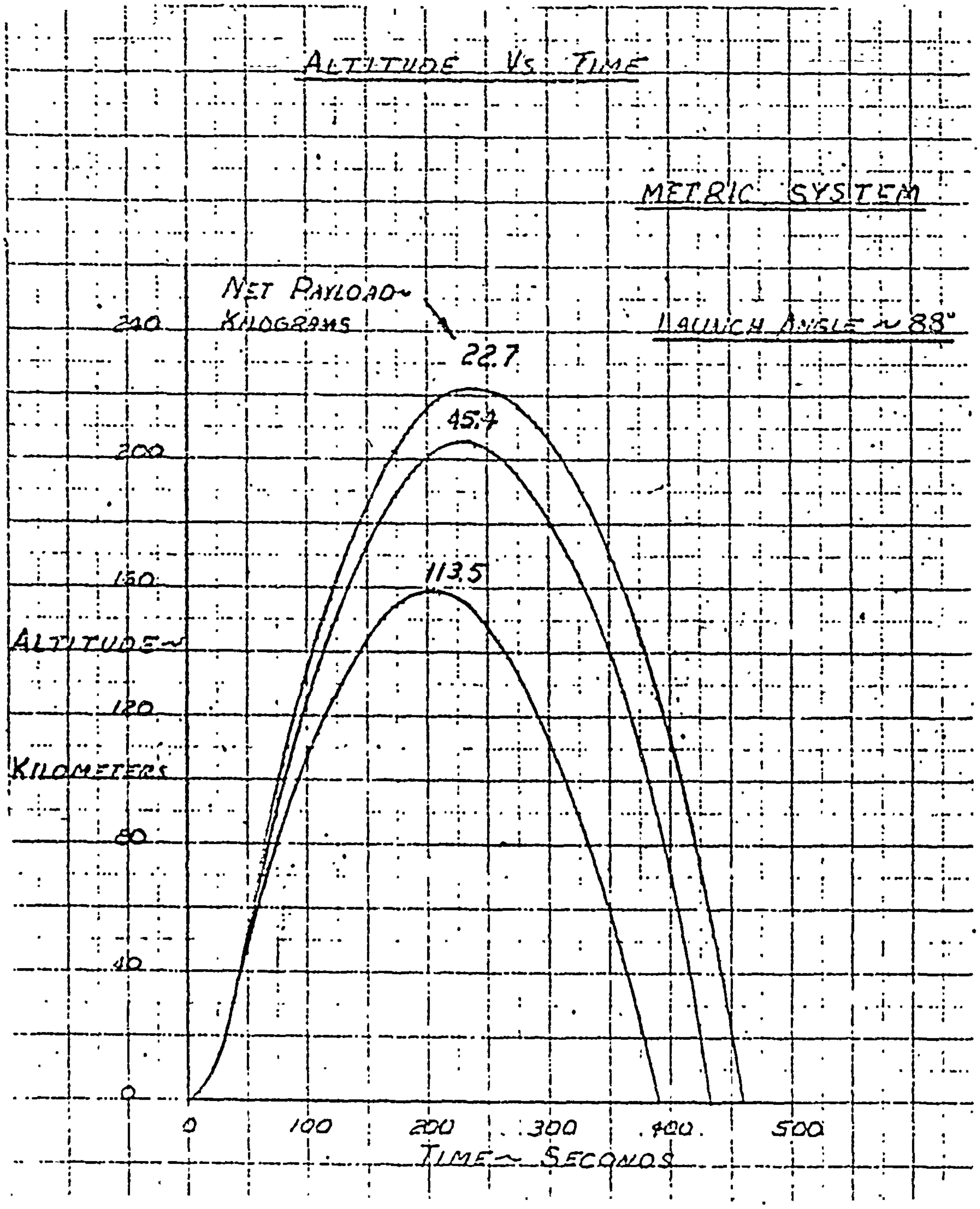

ALTITUDE VS TIME
METRIC SYSTEM
NET PAYLOAD ~ KILOGRAMS
LAUNCH ANGLE ~ 88°
22.7
45.4
113.5
ALTITUDE ~ KILOMETERS
240
200
160
120
80
40
0
0
100
200
300
400
500
TIME ~ SECONDS

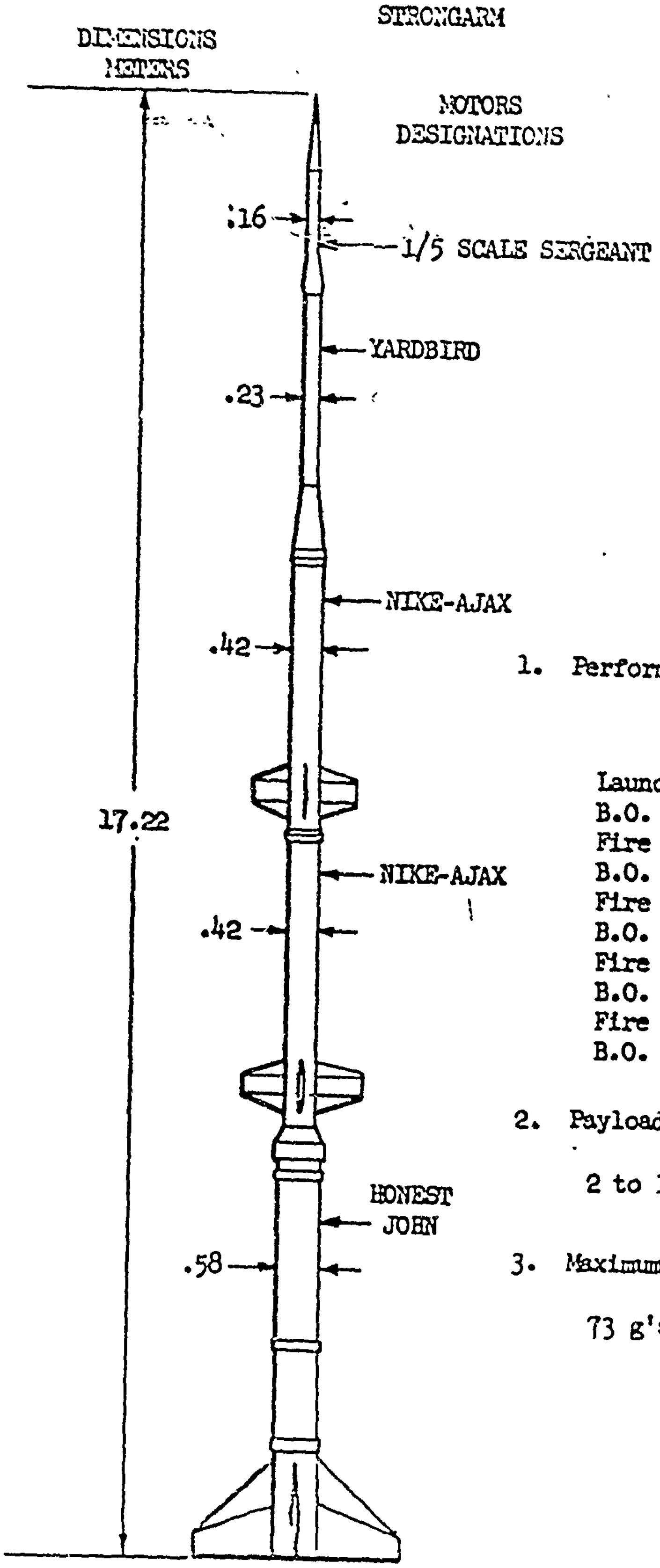
Fig. 51

19. STRONGARM

The Strongarm is administered by the University of Michigan under sponsorship of the Ballistic Research Laboratories of the United States Army, with design and launch assistance from the National Aeronautics and Space Administration, Langley Research Center. Figure 52 shows a sketch of the vehicle, staging weights, payload weight range, and maximum acceleration. Figure 53 shows the vehicle performance for various launch angles. Figure 54 shows a plot of altitude versus time for three payloads.

The Strongarm uses a solid propellant motor in each of its five steps. Fins on the first three steps and flares on the upper two steps are utilized for stabilization of the vehicle. The first step drag separates from the second stage. The second stage ignites, from delay squibs, approximately two seconds after separation of the first step. Normal burning pressure in the second step motor unlocks a device which prevents separation of the second step from the third stage until after second stage burning. At burnout, the second step drag separates. Then follows a coast period of approximately 15 seconds after which the third step motor fires by means of delay squibs. Pressure decrease at burnout of the third stage triggers the ignition of the fourth stage and similarly the fourth step motor pressure drop initiates the last stage firing. The nominal roll rate for Strongarm is zero. A simple beam launcher without a guide rail is required for firing the vehicle. Five firings have been made, of which the first was successful. A budgetary recurring cost for a vehicle is 28,545 dollars in lots of 10, not including the payload.

STRONGARM



1. Performance Weights Less Payload

	Kilograms
Launch	3280.
B.O. 1st	2291.
Fire 2nd	1391.
B.O. 2nd	1044.
Fire 3rd	798.6
B.O. 3rd	452.1
Fire 4th	212.1
B.O. 4th	90.54
Fire 5th	36.29
B.O. 5th	13.40

2. Payload Range

   2 to 12 Kilograms

3. Maximum Acceleration

   73 g's

Fig. 52

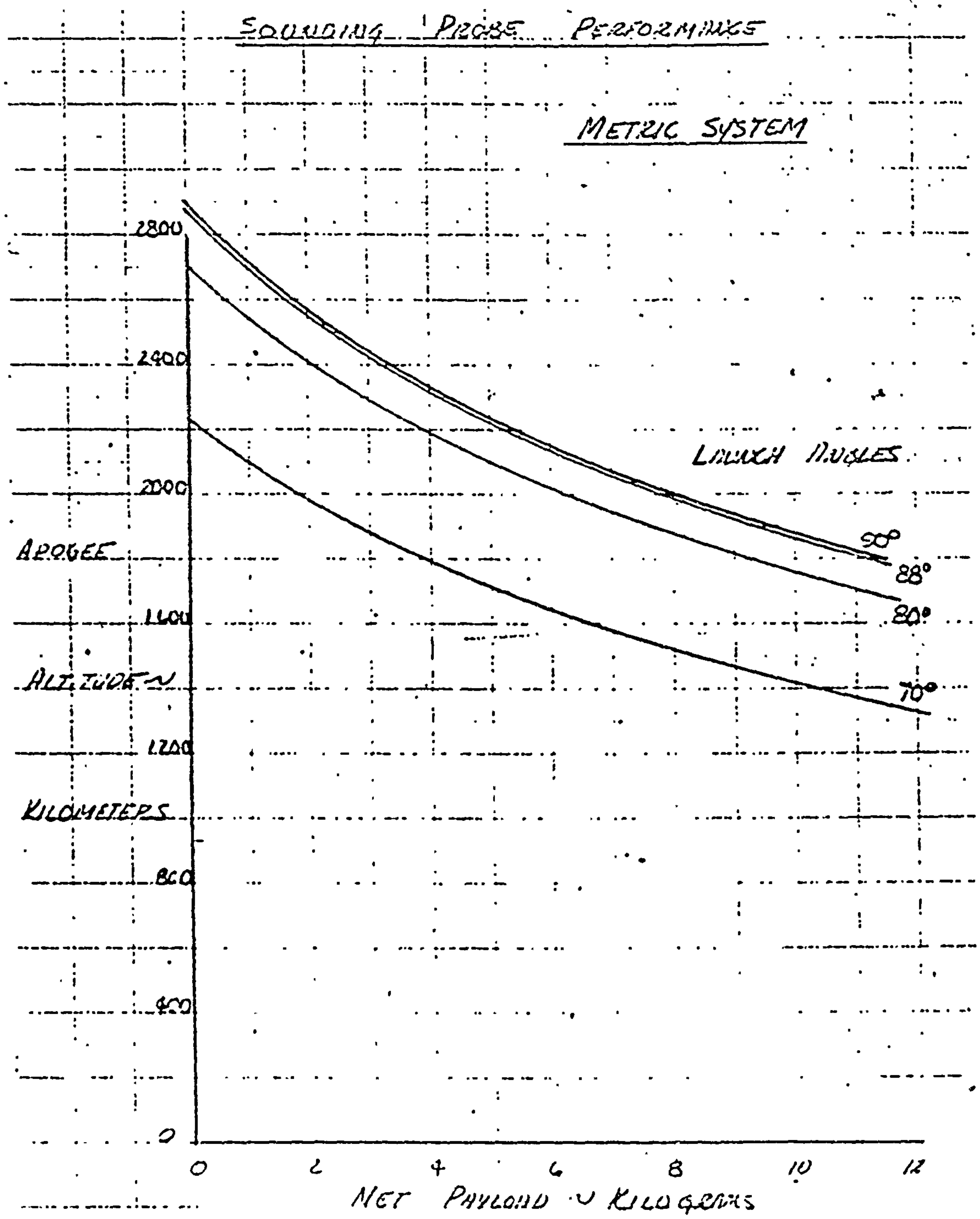
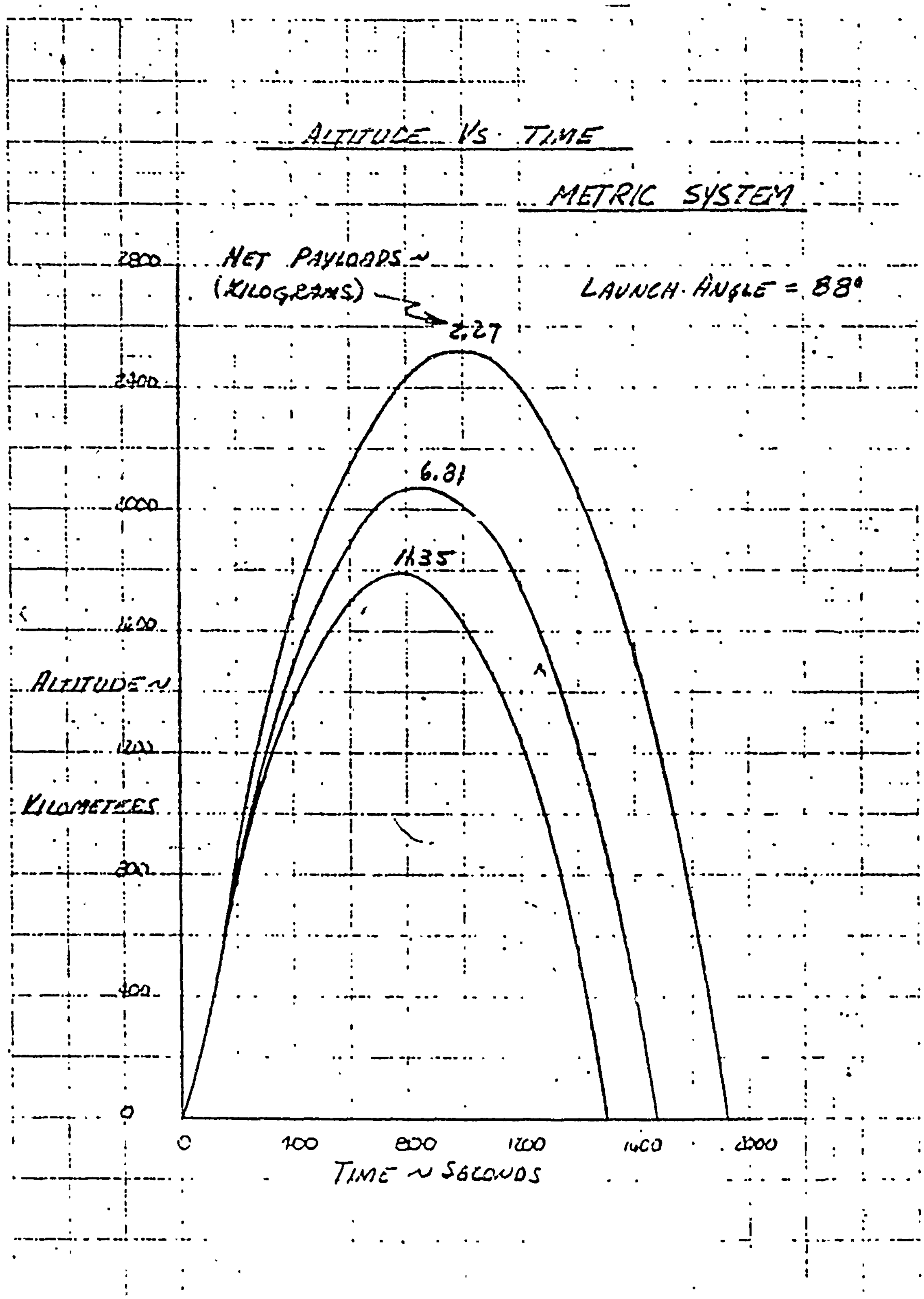

SOUNDING PROBE PERFORMANCE
METRIC SYSTEM
LAUNCH ANGLES
90°
88°
80°
70°
APOGEE ALTITUDE ~ KILOMETERS
2800
2400
2000
1600
1200
800
400
0
0
2
4
6
8
10
12
NET PAYLOAD ~ KILOGRAMS

Fig. 53



ALTITUDE VS TIME
METRIC SYSTEM
NET PAYLOADS ~ (KILOGRAMS)
LAUNCH ANGLE = 88°
2.27
6.81
11.35
ALTITUDE ~ KILOMETERS
2800
2400
2000
1600
1200
800
400
0
0
400
800
1200
1600
2000
TIME ~ SECONDS

Fig. 31

DISCUSSION

J.A. Hamilton (U.K.): Off all the test vehicles described by Mr. Russ, only one is launched from an aircraft. At the Royal Aircraft Establishment we have always fought shy of air-launching techniques because of the relatively complex operational problems involved. However, the system has certain attractions and it would be interesting to know if any other groups have used air-launching with success.

Author's reply; A rocket vehicle system was tried on the B-58 Hustler aircraft, but I do not know the degree of success it achieved. I should be glad to try to obtain further information for you.

J.G. Thibodaux (U.S.): In regard to airplane launching of sounding rockets, an airplane launch presents many operational problems and provides no more performance that cannot be obtained more easily and cheaply by the addition of another ground-launched stage.

Author's reply: I would like to say that many experiments are desired from where there is no launch site; therefore, the mobility of aircraft has this advantage for use as a first-stage and is worth further consideration.

ADDENDUM

AGARD SPECIALISTS' MEETING

ON

"THE USE OF ROCKET VEHICLES IN FLIGHT RESEARCH"

List of Papers Presented

Following is a list of the titles and authors, together with the AGARD Report number, of twenty three papers presented at the above Meeting held at Scheveningen, Holland, in July 1961.

ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT
Organisation du Traite de l'Atlantique Nord
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This Report is one in the Series 375-397, inclusive, presenting papers, with discussions, given at the AGARD Specialists' Meeting on 'The Use of Rocket Vehicles in Flight Research' at the Kurhaus Hotel, Scheveningen, Holland, 18-21 July 1961, sponsored by the AGARD Fluid Dynamics Panel.

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North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development
A STUDY OF SOUNDING ROCKET SYSTEMS
K.M. Russ
1961
73 pages incl. 51 figs., plus discussion and bibliography of papers presented at the 'Use of Rocket Vehicles in Flight Research' Meeting.

This paper presents, for each of 18 existing sounding rocket systems, a short description, a sketch with overall dimensions, weight and maximum acceleration data, and two performance charts - apogee altitude versus payload for various launch angles, and altitude versus time for various payloads at a launch angle of 88 degrees. The aim is to aid in the preliminary selection of a vehicle for a specific payload mission.

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